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Biological Sciences

POSTFIRE GAP-PHASE REGENERATION IN SCRUBBY FLATWOODS ON THE LAKE WALES RIDGE

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ABSTRACT: *We compared the densities of plant species in Lake Wales Ridge scrubby flatwoods communities between gaps and shrub-dominated (matrix) microsites across a chronosequence composed of sites differing in time since last fire. Gap areas were dynamic with over half of the landscape area in gaps and open sand following fire. However, the landscape quickly returned to a matrix-dominated state with prefire levels for gap size (mean: 1–2 m^2), gap area (mean: 12–18 %), and open sand (mean: 3–10 %) after three years postfire. Gap specialists, mainly herbs, comprised 28% of locally common and 84% of locally uncommon species. Variation in small ramet density was consistently correlated with time-since-fire for 11 of 18 common species. Microhabitat (gap or matrix) proved to be an important factor for four species, but gap size and percent litter in the gap did not generally affect ramet densities. Periodic fires or a fire mosaic are needed to create gaps, which may be especially critical for the regeneration and persistence of gap-dependent species in scrubby flatwoods communities. Time-since-fire is especially important for gap specialists in scrubby flatwoods in contrast to the weak coupling of gap availability with fire in the more open, xeric rosemary scrub.*

PATCH dynamic models have recognized the importance of natural disturbance in explaining community development and dynamics (Pickett and White, 1985). Because disturbances may be recognized at a number of scales (Levin, 1992) and occur with varying intensity and frequency (Kimmerer and Allen, 1982), the role of disturbance in a particular community must be considered within the context of the affected vegetation. In this paper, we will explore the possibility that periodic fire in Florida scrub communities facilitates the gap-phase regeneration of scrub species.

Florida scrub collectively describes the shrub-dominated, fire-prone vegetation of several Florida plant communities. Scrubby flatwoods is a type of Florida scrub dominated by scrub oaks (*Quercus inopina, Quercus geminata,* nomenclature follows Wunderlin, 1982) and palmettos (*Serenoa repens* and *Sabal etonia*), which is disturbed by periodic (5–20 year interval), high intensity fires (Menges and Hawkes, 1998). For many scrub species periodic fires can stimulate seed production, provide regeneration opportunities, and increase recruitment of new individuals (Hartnett and Richardson, 1989; Menges and Hawkes, 1998). The dominant species in scrubby flatwoods quickly resprout from underground rhizomes following fire (Menges and Kohfeldt, 1995) and peak in reproductive effort within 7 years postfire (Ostertag and Menges, 1994). Resprouting vegetation in scrubby flatwoods returns to preburn cover levels between 1 and 4 years postfire (Abrahamson, 1984). When unburned for 7–11 years, scrubby flatwoods is still highly resilient and recovers rapidly after fire (Schmalzer and Hinkle, 1992a), but scrubby flatwoods unburned for more than 35 years may not return to the typical composition of frequently burned scrubby flatwoods after a single burn (Abrahamson and Abrahamson, 1996). Vegetation changes during unburned periods appear to be structural, physiognomic, non-directional, and stochastic (Abrahamson, 1984; Givens et al., 1984; Menges et al., 1993).

The rosemary phase of sand pine scrub (Abrahamson et al., 1984; hereafter referred to as rosemary scrub), a community often adjacent to scrubby flatwoods, is dominated by Florida rosemary (*Ceratiola ericoides*). Compared to scrubby flatwoods, rosemary scrub is less productive, more open, and burns less frequently (15–60 year interval) and less continuously than scrubby flatwoods (Menges and Kohfeldt, 1995). These differences between scrubby flatwoods and rosemary scrub were related to differences in life-history characteristics and postfire abundance patterns of species specializing in the respective communities (Menges and Kohfeldt, 1995). Rosemary scrub specialists consisted of a greater proportion of obligate seeders that increased in density after fire. Scrubby flatwoods specialists typically resprouted and increased in density after fire (Menges and Kohfeldt, 1995).

Differences in gap dynamics and the availability of open space may also differ between scrubby flatwoods and rosemary scrub. Gap dynamics in these communities may be related to the fire regime at the landscape level and may be less dependent on local disturbances implicated in many gap models. Scrub gaps are presumably initiated and maintained within the intact matrix of scrub oaks and palmettos from stem die-back and defoliation following fire, but the role of these gaps in regeneration is unknown. Within gaps, fire consumes litter and plant cover to expose open sand (Hawkes and Menges, 1995; Menges and Kohfeldt, 1995; Schmalzer and Hinkle, 1992 a,b). The availability of open sand following fire corresponds with the productivity of the communities. In oak scrub on Merritt Island, open sand returned to low prefire levels within 3 years of fire (Schmalzer and Hinkle, 1992a). In contrast, open sand in rosemary scrub decreased for 10 years postfire, but older sites had persistent gaps of open space (Hawkes and Menges, 1996).

Open sand in gaps appears to be critical to the persistence of many xeric rosemary scrub species. In rosemary scrub, densities of most obligate-seeding or mixed strategy herbs increased with the amount of open sand among sites, while time-since-fire had little effect (Hawkes and Menges, 1996). The density and fecundity of *Polygonella basiramia* (Hawkes and Menges, 1995) and survival and fecundity of *Eryngium cuneifolium* (Menges and Kimmich, 1996) were highest in areas of open sand. Survival of *E. cuneifolium* (Menges and Kimmich, 1996) and *Hypericum cumulicola* (Quintana-Ascencio and Morales-Hernandez, 1997) was highest in microsites further from Florida rosemary (*Ceratiola ericoides*). The importance of gaps for rosemary scrub herbs suggests that gaps in scrubby flatwoods may also play a role in its vegetation dynamics.

This paper examines the role of gaps in plant regeneration following fire in scrubby flatwoods communities. We examine specialization for gaps, life-history characteristics associated with gap specialization, and ramet densities in relation to time-since-fire and gaps. Changes in gaps across the landscape and changes in individual gap characteristics are tested as predictors of changes in species ramet densities. Gap availability, time-since-fire, and gap characteristics may explain compositional and structural changes associated with the prolific postfire regeneration of scrubby flatwoods communities.

METHODS—We conducted this study at Archbold Biological Station (ABS) near Lake Placid, Florida, located on the Lake Wales Ridge. We selected a chronosequence of sites that varied in the year of the most recent burn (time-since-fire). Recovery trajectories of scrubby flatwoods species were then examined over this chronosequence.

We selected seven sites to minimize among-site heterogeneity in vegetation and past fire intensity. All sites were classified as *Quercus inopina* phase of the scrubby flatwoods association (Abrahamson et al., 1984) and mapped with a maximum fire intensity of 3, indicating consumption of litter and leaves by fire. The soils on these sites were deep, sandy, acidic soils with low clay and silt content and low water holding capacity (Abrahamson et al., 1984). Soil types (Duette, St. Lucie, Satellite, Pompano/Satellite, and Zolfo (Carter et al., 1989)) varied between sites from well drained to somewhat poorly drained, indicating differences in water table depth (Abrahamson et al., 1984). The seven sites selected had last been burned in 1994, 1993, 1991, 1990, 1987, 1984, and approximately 1959. We collected data at these sites from June-August 1994, creating a chronosequence of 0–35 years postfire.

We used the line-intercept method to quantify the fraction of land in gaps. At each site, 1–3 45 m transects were randomly located, beginning 1 m from a firelane and running perpendicular to it. Gaps intercepted by the transect were defined as open spaces (all ramets less than 50 cm height) with an area of at least 0.2 m^2 surrounded by vegetation greater than 50 cm in height. Slender projections radiating off the gap were not included as part of the gap if their length exceeded twice their width. Total transect length was 495 m at 7 sites and 137 gaps were encountered.

The fraction of land in gaps was estimated under the assumption that gaps are circular in shape, using an equation described for treefall gaps (Runkle, 1985):

$$e(X) = 1/L \sum_{j=1}^{n} X_j/d_j \quad \text{where} \quad X_j/d_j = (\pi * A_j)^{1/2}/2. \tag{1}$$

In this case, e(X) is an unbiased estimator of true mean gap size per unit area (X) determined by the equation:

$$X = 1/WL \sum_{j=1}^{n} X_j. \tag{2}$$

In these equations, L is the length of the transect through the site, WL is the area of the site, X_j is gap area of the jth gap, d_j is the diameter of the jth gap, A_j is the area of the jth gap intersected by the transect, and summations are over all n gaps encountered at the site.

We then located at least one 100 m^2 square macroplot per site; each macroplot was centered on a randomly selected point along a transect. We sampled vegetation in all gaps ($n = 207$) within the macroplots on all sites. In the macroplots, gaps bisected by the plot borders were sampled if more than 50% of the gap occurred in the plot. To estimate gap size, 8 radii lengths were measured in each of 8 compass directions. We estimated gap size as an irregular eight-sided polygon using trigonometric equations. We categorized ground cover using the line intercept method across the N–S and E–W diameters of each gap. Ground cover categories included litter, open sand, vascular plant cover (other than graminoids), graminoid cover, and ground lichen cover (by species). We also recorded the number of ramets (usually stems) of each species. By definition, ramets in the gap were less than or equal to 50 cm in height and were designated "small ramets". The product of the mean gap size, the mean amount of open sand in each gap, and the mean number of gaps as measured in the 100 m^2 macroplots, provided an index of open sand in gaps in each site.

We randomly selected at least 6 points along each transect to measure matrix (intact vegetation) composition. At each point ($n = 67$), the number of small ramets (50 cm or less in height) and the number of large ramets (greater than 50 cm in height) by species were counted separately in a 1 m^2 circular quadrat.

Statistical analyses were only conducted for locally "common" scrub species, defined as species with densities greater than 0.05 ramets/m^2. We used Student's t-tests to determine gap or matrix preferences of each species based on significant ($p < 0.05$) differences in mean ramet density in gaps across all burn years. We also characterized life history attributes including postfire recovery mechanism (seeder, resprouter, clonal grower, or mixed strategies with any combination of the above) and growth habit (herbaceous perennial, woody perennial, or vine) based on Menges and Kohfeldt (1995). Life history characteristics were compared between gap specialist and non-specialist species using Fisher's exact test. Relationships between time-since-fire, microhabitat, and species densities were evaluated using two-way ANOVA with a 2 × 7 factorial design. Relationships between gap characteristics and time-since-fire were tested with simple ANOVA and linear, bivariate regression analysis with SPSS (Norusis, 1993). For two-way and simple ANOVAs, type 3 sums of squares were used. Increasing, decreasing, humped, and non-monotonic trends in ramet density within gaps were determined using simple ANOVA.

RESULTS—The fraction of land in gaps, as estimated with line intercepts, declined steadily during the first three years following fire from 42.5% to 29.9% (Fig. 1). After this point, the fraction of land in gaps remained between 8.3%–16.7%. Open sand within gaps decreased dramatically during the first three years following fire from 63.8% to 6.0% (Fig. 1). Thereafter, the amount of open sand in gaps ranged between 3.2–9.7% (Fig. 1).

With time-since-fire, mean gap size decreased ($SS = 923.47$, $F = 13.28$, $df = 206$, $p = 0.00$) (Fig. 2), mean litter cover increased ($SS = 24.08$, $F = 46.44$, $df = 207$, $p = 0.00$) (Fig. 3), and mean open sand (Fig. 3) decreased significantly ($SS = 20.30$, $F = 55.93$, $df = 207$, $p = 0.00$). *Cladonia sub-*

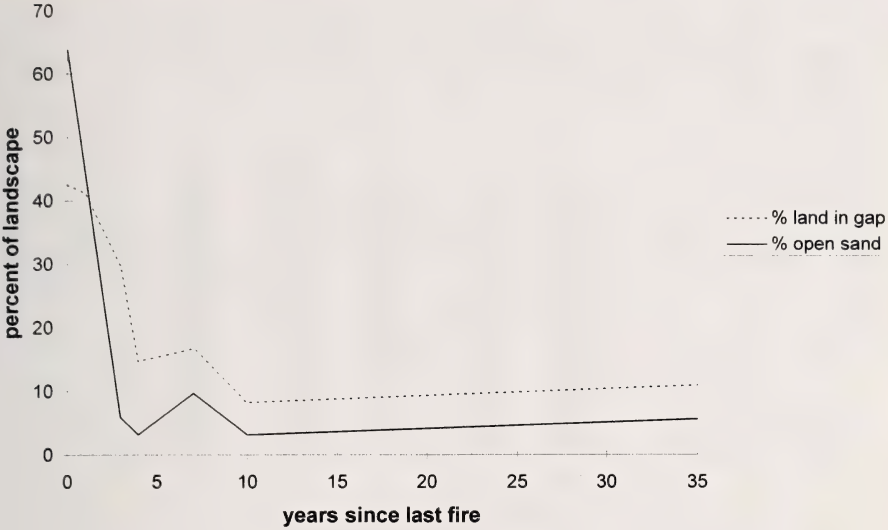

FIG. 1. The relationship between the percentage of land occupied by gaps and percentage of open sand in gaps with time since last fire. Sample sizes are as follows: 0 yrs., n = 23; 1 yr., n = 35; 3 yrs., n = 16; 4yrs., n = 12; 7 yrs., n = 7; 35 yrs., n = 8.

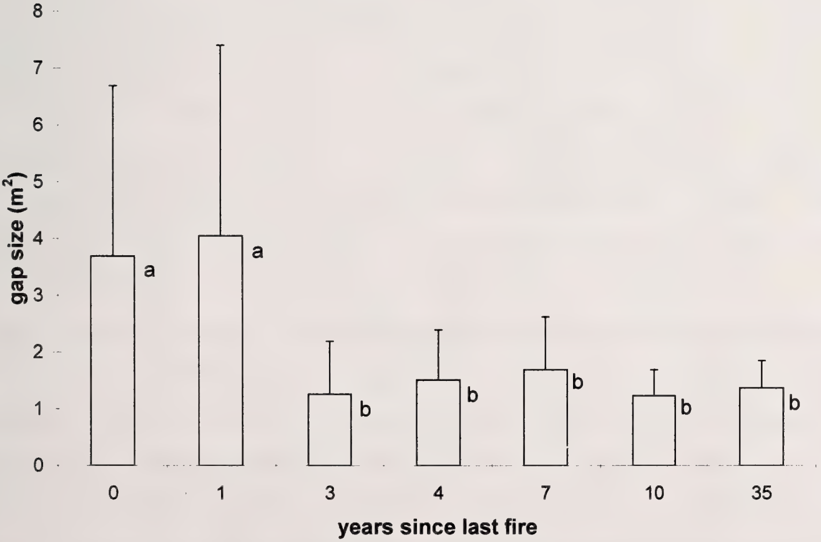

FIG. 2. Changes in mean gap size in relation to time since last fire. SS = 923.47 F = 13.28, p = 0.00. Bars represented by the same letter are not significantly different ($p < 0.05$). Error bars represent 1 standard deviation. Sample sizes are as follows: 0 yrs., n = 21; 1 yr., n = 35; 3 yrs., n = 48; 4yrs., n = 33; 7 yrs., n = 29; 10 yrs., n = 17, 35 yrs., n = 24.

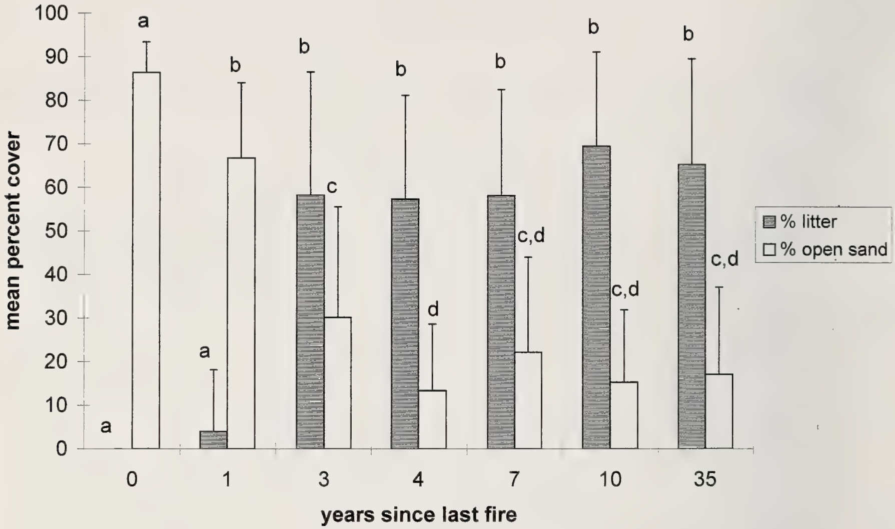

FIG. 3. Changes in gap characteristics (litter cover and open sand) in relation to time since last fire. Litter cover: SS = 24.08, F = 46.44, p = 0.00. Open sand: SS = 20.30, F = 55.93, p = 0.00. Bars represented by the same letter are not significantly different ($p < 0.05$). Error bars represent 1 standard deviation. Sample sizes are as follows: 0 yrs., n = 21; 1 yr., n = 35; 3 yrs., n = 48; 4yrs., n = 34; 7 yrs., n = 29; 10 yrs., n = 17, 35 yrs., n = 24.

tenuis cover increased (SS = 0.22, F = 8.52, df = 207, p = 0.00), and plant cover in gaps showed a generally humped distribution, peaking at 1–4 years since fire (SS=6.10, F=9.85, df=207, p=0.00). Relationships between time-since-fire and grass cover and *Cladonia leporina* cover were not significant.

Of 18 locally common species (densities ≥ 0.05 small ramets/m^2), five species (27.8%) showed a significant preference for gaps ($p < 0.05$) and only one (5.6%) for the matrix (Table 1). Small ramets preferentially in gaps were: *Galactia regularis, Lechea deckertii, Palafoxia feayi, Selaginella arenicola,* and *Vaccinium myrsinites.* The matrix supported only one preferential species: *Quercus chapmanii.* No preference for gap or matrix sites was observed for 12 "gap-neutral" species (Table 1). These 18 common species served as the data set used for all further statistical analyses. Of the 19 locally uncommon species (ramet density < 0.05 ramets/m^2), 16 (84.2%) had a distribution restricted to gaps (Table 2).

Resprouters were common among all gap groups, accounting for 4 of 5 gap specialists and 11 of 13 non-gap species (1 matrix specialist + 12 gap-neutral species) (Table 1, two-tailed Fisher's exact test, $p > 0.05$). Clonal growth occurred in 1 gap specialist and in 7 non-gap species (Table 1, two-tailed Fisher's exact test, $p > 0.05$). Postfire seedling recruitment is known for 4 of 5 gap specialists, and in 4 of 13 non-gap species (Table 1, two-tailed Fisher's exact test, $p > 0.05$). Herbaceous species accounted for 3 gap specialists and 1 non-gap species (Table 1, two-tailed Fisher's exact test, p

TABLE 1. Comparisons between small ramet densities (per m^2) in gaps ($n = 207$) and matrix ($n = 67$) for locally common plant species[3] in scrubby flatwoods.

Species	Reproductive mode[1]	Growth habit[2]	Density in gap	Density in matrix	p-Value for density differences, two-tailed t-test
Preference for gaps ($p < .05$)					
Galactia regularis	R + S	H + V	0.13	0.015	0.010
Lechea deckertii	R + S	H	0.63	0.015	0.001
Palafoxia feayi	R + S	W	0.45	0.13	0.011
Selaginella arenicola	S	H	2.46	0.27	0.000
Vaccinium myrsinites	R + C	W	5.10	2.16	0.012
Preference for matrix ($p < .05$)					
Quercus chapmanii	R + C	W	0.41	1.75	0.001
No preference for gaps or matrix ($p > .05$)					
Dalea feayi	S	H	0.058	0.0000	0.14
Gaylussacia dumosa	R + C	W	4.72	2.67	0.10
Licania michauxii	R + C	W	1.91	0.90	0.18
Lyonia ferruginea	R	W	0.16	0.075	0.55
Lyonia fruticosa	R + C	W	2.54	1.27	0.13
Lyonia lucida	R + C	W	1.33	2.75	0.063
Persea humilis	R	W	0.012	0.075	0.062
Polygonella polygama	S	W	0.032	0.060	0.65
Quercus geminata	R + C	W	2.42	2.79	0.60
Quercus inopina	R + C	W	4.33	4.02	0.76
Sabal etonia	R + S	W	0.14	0.10	0.71
Serenoa repens	R + S	W	0.46	0.28	0.077

[1] Taken from Menges and Kohfeldt (1995); S = seeder; R = resprouter (sprout ≤ 20 cm from parent plant); C = clonal growth (sprout > 50 cm from parent plant).

[2] Taken from Menges and Kohfeldt (1995); H = herbaceous perennial; W = woody perennial; V = vine.

[3] Locally common plant species are species with a ramet density ≥ 0.05 ramets/m^2.

< 0.05). Most of the locally uncommon gap species were herbaceous plants and/or seeders (Table 2).

Time-since-fire and microhabitat (gap vs. matrix) affected small ramet densities of some scrubby flatwoods species. Eleven of eighteen common species (61%) were affected by time-since-fire (two-way ANOVAs, $p < 0.05$), although patterns were generally non-monotonic (Table 3). Microhabitat (gap or matrix) significantly affected small ramet density for only 4 species (22.2%). An interaction between time-since-fire and gap microhabitat occurred in 3 species (16.7%). Directional trends for species' ramet densities in gaps included 2 increasing, 2 decreasing, 4 humped, 2 non-monotonic, and 8 stable (no change across years). Time-since-fire results were significant

TABLE 2. A comparison of small ramet densities between gap and matrix for locally uncommon[1] plant species in scrubby flatwoods.

Species	Mean density in gaps	Mean density in matrix
Asclepias curtissii	0.0013	0.00
Asimina obovata	0.0053	0.00
Balduina angustifolia	0.0094	0.00
Befaria racemosa	0.0096	0.015
Ceratiola ericoides	0.0034	0.00
Cnidosculus stimulosus	0.0069	0.00
Euphorbia floridana	0.0083	0.00
Garberia fruticosa	0.0017	0.00
Gratiola ramosa	0.015	0.00
Ilex opaca var. *arenicola*	0.0043	0.045
Liatris tenuifolia	0.0035	0.00
Myrica cerifera	0.0097	0.00
Opuntia humifusa	0.016	0.00
Paronychia chartacea	0.048	0.00
Quercus minima	0.047	0.00
Smilax auriculata	0.0040	0.00
Stipulicida setacea	0.036	0.015
Vaccinium darrowi	0.034	0.00
Ximenia americana	0.0039	0.00

[1] Locally uncommon species are species with ramet densities < 0.05 ramets/meter^2.

for small ramets in gaps (13 of 18 species), but generally not for small (2 of 18 species) or large ramets (1 of 18 species) in the matrix (one-way ANOVAs, results not shown).

Percent litter predicted small ramet densities of only two species (*Galactia regularis,* $r = -0.20$, $p < 0.01$ and *Quercus inopina,* $r = -0.29$, $p < 0.001$). Litter cover within gaps was inversely related to total plant cover across all sites ($r = -0.41$, $p < 0.001$). Gap size was positively correlated with the abundance of *Quercus inopina* ($r = 0.28$, $p < 0.001$) and with the amount of open sand in a gap ($r = 0.45$, $p < 0.001$). Open sand and litter were strongly negatively correlated ($r = -0.85$, $p < 0.001$). However, most species' densities were independent of microhabitat variables within gaps. In three-way ANOVAs, percent litter and gap size were always less important than time-since-fire in predicting ramet densities (results not shown).

DISCUSSION—Gap areas were dynamic in scrubby flatwoods following fire. The fraction of land in gaps increased immediately following fire, but returned to near long-unburned levels within 4 years. This is consistent with the 1–4 and 3–4 year recovery time for plant cover in oak-dominated scrub suggested by Abrahamson (1984) and Schmalzer and Hinkle (1992a), respectively. Open sand became less available over time, as the mean gap size decreased and litter cover increased. These trends are in agreement with the increasing levels of standing biomass and leaf litter detected up to eight years following fire in oak scrub on Merritt Island (Schmalzer and Hinkle, 1996). The rapid return of the fraction of land in gaps and open sand to preburn levels presents a fairly short window of opportunity for exploitation by gap specialists. However, even in the long-unburned site, gap microsites were not totally eliminated, as gap area, gap size, open sand, and litter tended to stabilize at low levels.

More locally common species specialized in gaps (n = 5) than in the shrub matrix (n = 1). In addition, the great majority (84.2%) of locally uncommon species occurred exclusively in gaps. Dominant shrubs, including *Quercus inopina, Q. geminata, Sabal etonia* and *Serenoa repens,* regenerate equally well in gaps as within the competitive shrub matrix. Gap specialists were herbaceous more often than expected compared to non-gap species, but did not differ from non-gap species in resprouting, clonal growth, or seeding recovery modes. The rapid resprouting of scrub oaks and palmettos may leave gaps as the only available sites for herbs, which are likely to be weak competitors. However, unlike open sand specialists in rosemary scrub (Menges and Kohfeldt, 1995; Hawkes and Menges, 1996), the common gap specializing species in scrubby flatwoods frequently utilize resprouting as a postfire recovery mode.

Ramet densities of many species varied with time-since-fire, especially within gaps. The tendency for small ramet densities of several herbaceous and woody perennials to show decreasing and humped patterns with many peaks (33.3%) occurring within the first four years postfire suggests that gaps are important sites for regeneration. Most non-dominant resprouting shrubs decline in ramet densities with time-since-fire. However, two species, *Dalea feayi* and *Selaginella arenicola,* with long periods of increasing ramet densities following fire, regenerate exclusively from seeds.

Landscape level changes in gap characteristics such as size and litter cover were related to time-since-fire, although gap characteristics apparently did not generally affect ramet densities independent of time-since-fire. However, total vascular plant cover in gaps decreased as litter cover increased. The increasing cover of *Cladonia subtenuis* in long-unburned stands may impact plant composition in gaps, as lichens were observed to displace obligate seeders in rosemary scrub (Johnson and Abrahamson, 1990).

In scrubby flatwoods, gaps are utilized as a preferred microhabitat for several species and characteristic abundance patterns following fire are due in part to the opportunity for regeneration provided by gaps. This pattern is analogous to patterns observed in rosemary scrub. However, in rosemary scrub, long-unburned sites have over 15% of the area in gaps with persistent gaps typically not less than 10 m^2. Therefore, species abundances in xeric, open rosemary scrub are determined by the area of the site in gaps and not time-since-fire (Hawkes and Menges, 1996). In scrubby flatwoods, open sand and time-since-fire are coupled more tightly. Open sand is abundant for fewer than four years before dropping to less than 10% cover (this study) or less (Schmalzer and Hinkle, 1992a) of the landscape.

The recognition of gap specialists, the enhanced effect of time-since-fire

TABLE 3. Two-way ANOVA for small ramet densities of common species in scrubby flatwoods with time since fire and microhabitat.

Species		SS	df	MS	F	p
Dalea feayi	microhabitat	0.40	1	0.40	1.78	0.18
	time since fire	4.98	6	0.83	3.73	0.001** (i)
	interaction	2.71	6	0.45	2.03	0.06
Galactia regularis	microhabitat	0.47	1	0.47	1.88	0.17
	time since fire	3.73	6	0.62	2.51	0.02* (s)
	interaction	1.38	6	0.23	0.93	0.47
Gaylussacia dumosa	microhabitat	429.11	1	429.11	2.25	0.13
	time since fire	4838.72	6	806.45	4.24	0.00*** (nm)
	interaction	730.182	6	121.70	0.64	0.70
Lechea deckertii	microhabitat	19.97	1	19.97	5.42	0.02* (G)
	time since fire	234.52	6	39.09	10.61	0.00*** (h, 1987)
	interaction	81.50	6	13.58	3.69	0.00***
Licania michauxii	microhabitat	40.66	1	40.66	0.69	0.41
	time since fire	1317.91	6	219.65	3.72	0.00*** (h, 1993)
	interaction	252.13	6	42.02	0.71	0.64
Lyonia ferruginea	microhabitat	0.17	1	0.17	0.07	0.80
	time since fire	10.39	6	1.73	0.67	0.67 (s)
	interaction	4.42	6	0.74	0.29	0.94
Lyonia fruticosa	microhabitat	74.40	1	74.40	0.94	0.33
	time since fire	968.33	6	161.39	2.05	0.06 (nm)
	interaction	371.17	6	61.86	0.78	0.58
Lyonia lucida	microhabitat	42.61	1	42.61	2.11	0.15
	time since fire	495.14	6	82.52	4.09	0.00*** (s)
	interaction	131.61	6	21.94	1.09	0.37
Palafoxia feayi	microhabitat	4.28	1	4.28	2.13	0.15
	time since fire	13.76	6	2.29	1.14	0.34 (s)
	interaction	7.24	6	1.21	0.60	0.73
Persea humilis	microhabitat	0.11	1	0.11	2.00	0.16
	time since fire	0.70	6	0.12	2.06	0.06 (s)
	interaction	0.44	6	0.07	1.32	0.25
Polygonella polygama	microhabitat	0.03	1	0.03	0.32	0.57
	time since fire	1.13	6	0.19	2.00	0.07 (s)
	interaction	1.023	6	0.17	1.82	0.10
Quercus chapmanii	microhabitat	94.73	1	94.73	12.98	0.00*** (M)
	time since fire	77.14	6	12.86	1.76	0.11 (s)
	interaction	91.35	6	15.23	2.09	0.06
Quercus geminata	microhabitat	17.62	1	17.62	0.95	0.33
	time since fire	512.87	6	85.48	4.59	0.00*** (d)
	interaction	44.83	6	7.47	0.40	0.88
Quercus inopina	microhabitat	0.94	1	0.94	.027	0.87
	time since fire	4920.42	6	820.07	23.24	0.00*** (h, 1993)
	interaction	51.19	6	8.53	0.24	0.96
Sabal etonia	microhabitat	0.04	1	0.04	0.10	0.75
	time since fire	1.70	6	0.28	0.69	0.66 (s)
	interaction	1.75	6	0.29	0.71	0.64

TABLE 3. Continued.

Species		SS	df	MS	F	p
Selaginella arenicola	microhabitat	363.07	1	363.07	14.72	0.00*** (G)
	time since fire	2194.22	6	365.70	14.83	0.00*** (i)
	interaction	708.45	6	118.08	4.79	0.00***
Serenoa repens	microhabitat	1.05	1	1.05	1.22	0.27
	time since fire	21.33	6	3.56	4.14	0.00*** (d)
	interaction	5.08	6	0.85	0.99	0.43
Vaccinium myrsinites	microhabitat	484.51	1	484.51	5.64	0.02*(G)
	time since fire	8956.33	6	1492.72	17.36	0.00*** (h, 1990)
	interaction	1128.44	6	188.07	21.9	0.05

* = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$.

Trends for microhabitats are based on two-way ANOVA: G = higher density in gaps; M = higher density in matrix.

Trends for time since fire are based on one-way ANOVA for ramet densities in gaps only: i = increasing ramet density with time since fire; d = decreasing ramet density with time since fire; h = humped, monotonic pattern of ramet density with time since fire (year indicates year last burned for site of peak ramet density); nm = complex, non-monotonic pattern; s = stable (no change across years).

on small ramet density in gaps compared to the matrix, and the decrease in plant cover in gaps with decreasing open sand between fires suggests that gaps serve as important microhabitat for some species by providing opportunities for regeneration and/or growth. Periodic burning enlarged gaps and reduced litter within gaps for three years. Maintaining these microhabitats in the fire mosaic will be important for maintaining species diversity in scrubby flatwoods and may be especially critical for gap-specialists with sensitive life-history characteristics, such as a transient seed bank or limited dispersal efficiency.

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SCRUB ECOSYSTEMS OF BREVARD COUNTY, FLORIDA: A REGIONAL CHARACTERIZATION

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ABSTRACT: *Florida scrub is disappearing throughout its range. Brevard County contains regionally important scrub ecosystems; these support some of the largest remaining populations of the Florida Scrub-Jay (*Aphelocoma coerulescens*) and other species of conservation concern. Scrub in Brevard County is distributed across five distinct landscapes: Cape Canaveral and the outer barrier island, Merritt Island, the Atlantic Coastal Ridge, the Ten Mile Ridge, and the Osceola Plain Ridge. These landscapes differ in geologic history, topography, elevation, and soils. Scrub vegetation differs across these landscapes. Coastal strand and scrub occur on Cape Canaveral and the outer barrier island. Sand pine scrub occurs primarily on the Atlantic Coastal Ridge. Oak scrub and scrubby flatwoods are common on Merritt Island, the Atlantic Coastal Ridge, and the Ten Mile Ridge but also occur on the western side of Cape Canaveral. Distributions of rare scrub plants differ across these landscapes.* Cereus gracilis *var.* simpsonii *(prickly apple),* Chamaesyce cumulicola *(sand dune spurge),* Glandularia maritima *(coastal vervain),* Lantana depressa *var.* floridana *(Atlantic Coast Florida lantana), and* Tephrosia angustissima *var.* curtissii *(coastal hoary-pea) occur in coastal scrub of Cape Canaveral or the outer barrier island.* Dicerandra thinicola *is found only in a small area of the Atlantic Coastal Ridge.* Conradina grandiflora *(large-flowered rosemary) occurs on the Atlantic Coastal Ridge and the Ten Mile Ridge. Rare scrub fauna also occur differently across these landscapes. The Florida Scrub-Jay,* Gopherus polyphemus *(gopher tortoise), and* Drymarchon corias couperi *(eastern indigo snake) occur on Cape Canaveral, Merritt Island, the Atlantic Coastal Ridge, and the Ten Mile Ridge.* Pituophis melanoleucus mugitus *(Florida pine snake) is known from Cape Canaveral, Merritt Island, and the Atlantic Coastal Ridge.* Podomys floridanus *(Florida mouse) and* Rana capito aesopus *(Florida gopher frog) occur on Merritt Island and the Atlantic Coastal Ridge.* Sceloporus woodi *(Florida scrub lizard) and* Tantilla relicta neilli *(Florida crowned snake) occur on the Atlantic Coastal Ridge. Federally-owned areas of scrub (4,455.9 ha) are found within Kennedy Space Center/Merritt Island National Wildlife Refuge (1,559.2 ha) and Cape Canaveral Air Station (2,896.7 ha). The remaining scrub of the Atlantic Coastal Ridge (4,436.0 ha), the Ten Mile Ridge (592.0 ha), and the southern end of the outer barrier island (382.4 ha) is the focus of county and state scrub conservation efforts. Fire suppression and landscape fragmentation have degraded scrub habitat throughout the county. Intensive management through prescribed burning and restoration are needed to ensure the survival of scrub ecosystems and species.*

FLORIDA scrub is a rare and vanishing ecosystem (Myers, 1990). Brevard County, in east-central Florida, contains regionally important scrub ecosystems; these support some of the largest remaining populations of the Florida Scrub-Jay (*Aphelocoma coerulescens*) and other species of conservation concern (Larson, 1992; Swain et al., 1995; Stith et al., 1996). Scrub in Brevard County has been reduced greatly by urban development and agriculture, but efforts are underway to conserve and manage important remaining areas.

Some authors (e.g., Laessle, 1942; 1958; Abrahamson et al., 1984) define scrub in Florida to be communities characterized by a sand pine (*Pinus clausa*) canopy with oaks or Florida rosemary (*Ceratiola ericoides*) comprising the major component of the shrub layer. Here, we use scrub more broadly for xeromorphic shrub communities dominated by evergreen oaks (e.g., *Quercus geminata, Q. myrtifolia, Q. chapmanii*) or Florida rosemary with or without a pine overstory (Kurz, 1942; Myers, 1990). Included are sand pine scrub, oak scrub, Florida rosemary scrub, coastal scrub, and scrubby flatwoods (Myers, 1990).

Snodgrass and co-workers (1991) mapped well-drained scrub in Brevard County, excluding Federal property and developed areas, and estimated that 4,605 ha of scrub habitat remained. This included 1,595 ha of oak scrub, 1,726 ha of scrubby flatwoods, 1,017 ha of sand pine scrub, and 268 ha of coastal strand/coastal scrub. They estimated that this represented a 78% reduction from that originally occurring assuming that all the Paola-Pomello-Astatula soil association (16,228 ha) and the Canaveral-Palm Beach-Welaka soil association (12,707 ha) (Huckle et al., 1974) once supported scrub. This assumption probably overestimated the original extent of scrub, because the soil associations include areas of poorly-drained soil series that do not support scrub. Most remaining scrub was fragmented into patches <4 ha. Larger remaining scrub areas (actual size not specified) identified included: the South Lake-Fox Lake area west of Titusville, the Titusville Well Field and Space Center Executive (TICO) Airport, the scrub ridge between Rockledge and Eau Gallie, the Goat Creek and Valkaria Airport area, the southern end of the Ten Mile Ridge, and the Sebastian River/C-54 Canal area.

Bergen (1994) estimated that the total area of scrub had decreased by 68.8% between 1943 and 1991 in northern Brevard County, defined as the Atlantic Coastal Ridge north of Cocoa. Mean patch size had decreased from 37.6 ha to 7.4 ha, indicating the fragmentation of remaining scrub. Schmalzer and co-workers (1996) estimated that scrub remaining within the Courtenay topographic quadrangle (primarily Merritt Island) in 1990 was only 3.5% of that present in 1920.

In this paper, we provide a regional characterization of scrub ecosystems in Brevard County. Interest in scrub in Brevard County has increased in recent years, and new surveys and studies have been conducted. Scrub on Kennedy Space Center (KSC), Merritt Island, has been studied since the 1970s (Sweet, 1976; Stout, 1980; Schmalzer and Hinkle, 1985; 1987; 1991; 1992a; 1992b; 1996; Schmalzer et al., 1994; 1996; Breininger, 1989; 1992b; Breininger and Schmalzer, 1990; Breininger and Smith, 1992; Breininger et al., 1988; 1991; 1994b; 1995; 1996a; 1996b; Duncan et al., 1995; 1996). Initiation of the Brevard County Environmentally Endangered Lands Program, a county land acquisition program, in 1990 (Swain et al., 1993) led to examination of many scrub areas on the mainland of Brevard County

(Hames, 1995; Schmalzer, unpublished) and to the preparation of the Scrub Jay Refugia Conservation and Recreational Land (CARL) proposal in 1992 (Environmentally Endangered Lands Program [EELP], 1992b). CARL is the state land acquisition program in Florida, funded by the ten-year, $300 million per annum Preservation 2000 Program. Between 1993 and 1995, Brevard County engaged in a Habitat Conservation Planning process regarding scrub and the Florida Scrub-Jay; this was known as the Scrub Conservation and Development Plan (SCDP). As a part of this planning process, information was collected systematically on remaining scrub in the county outside Federal ownership (Swain et al., 1995; Boyle, 1996; Noss et al., 1997). Scrub-Jay populations also were surveyed as part of a state-wide study (Stith et al., 1996). As a result of all these studies, the Coastal Scrub Ecosystem Initiative CARL proposal was developed (EELP, 1995), which expanded the previous CARL land acquisition proposal.

Here we use the geology of scrub ridges in Brevard County to organize information on the distribution of scrub soils, vegetation, and selected rare or declining species. We conduct a spatial analysis using soil and vegetation coverages, and we examine the conservation status of these ecosystems.

Geology of scrub formations in Brevard County—Scrub vegetation is associated with ridges of well-drained to moderately well-drained soils (Kurz, 1942; Laessle, 1942; 1958). Within Brevard County, scrub occurs on five distinct landscapes with different geologic histories and combinations of soils. These are: 1) the recent barrier islands including Cape Canaveral, 2) Merritt Island, 3) the Atlantic Coastal Ridge, 4) the Ten Mile Ridge, and 5) a small ridge, the Osceola Plain Ridge, in the southwestern corner of the county (Fig. 1). These areas differ in age and topography, but all have a similar origin as coastal dunes.

Florida has a complex geologic history with repeated periods of deposition when the Florida Plateau was submerged and erosion when the seas recessed (Randazzo, 1997; Scott, 1997). The oldest formation known to occur beneath Brevard County, the Avon Park limestone, was deposited in the early Eocene in an open ocean (Cooke, 1945). This was followed by a withdrawal of the sea and a period of erosion. In the late Eocene, the seas advanced and limestones of the Ocala group were deposited (Cooke, 1945). Following another period of recession of the sea and erosion of the land surface, the Hawthorn formation of calcareous clay, phosphatic limestone, phosphorite, and radiolarian clay was deposited in the late Miocene (Cooke, 1945; Brown et al., 1962). Overlying this are unconsolidated beds of fine sand, shells, clay, and calcareous clay of late Miocene or Pliocene age (Brown et al., 1962). Surface strata in Brevard County are primarily unconsolidated white to brown quartz sand containing beds of sandy coquina of Pleistocene and Holocene (= Recent) age (Brown et al., 1962).

In addition to the sequences of sediments of varying age, the surface of Florida is marked by a series of terraces and former shorelines of varying ages. In Brevard County, two terraces have been recognized, the Silver Bluff Terrace on Cape Canaveral and Merritt Island and the Pamlico Terrace on the mainland (Healy, 1975).

During the Pleistocene (ca. 1.6 million years before present [yr B.P.] to 13,000 yr B.P.), repeated glaciation of the northern hemisphere produced fluctuations in sea level (Bowen, 1978). At the maximum of the Wisconsinan glaciation (ca. 18,000 yr B.P.), sea levels were on the order of 100 m lower than at present, and substantial additional areas were exposed along the Atlantic and Gulf coasts, including Florida (Field and Duane, 1974; Delcourt and Delcourt, 1981).

The alternating high and low sea stands of the Pleistocene and Holocene (since ca. 13,000 yr B.P.) shaped the surface of Brevard County. The outer barrier island and Cape Canaveral formed after sea levels rose when the Wisconsinan glaciers retreated (Davis, 1997). Cape Canaveral is mapped as Holocene in age (Brooks, 1981). Brooks (1972) suggested that the formation of the Cape Canaveral peninsula began about 7,000 years ago. Cape Canaveral is part of a prograding barrier island complex, the result of southward growth of an original cape at the site of the present False Cape (White, 1958; 1970). Multiple dune ridges on Cape Canaveral, which are too fine a scale to detect on Fig. 1, suggest that periods of deposition and erosion alternated (Chaki, 1974). The barrier island separating Mosquito Lagoon from the Atlantic Ocean also originated about 7,000 years ago (Mehta and Brooks, 1973). However, its history has been marked by erosion, overwash, and landward migration rather than progradation; these processes continue today (Mehta and Brooks, 1973). Some areas of the barrier island south of Cape Canaveral have a history of overwash, while others have been more stable (Bader and Parkinson, 1990). The ridge on the barrier island separating the Indian River Lagoon from the Atlantic Ocean was almost certainly continuous before settlement; however, coastal development, visible as urban soil types in Huckle and co-workers (1974), has fragmented the barrier island ridge (Fig. 1).

Merritt Island also formed as a prograding barrier island complex; the eastern edge of Merritt Island at its contact with the Mosquito Lagoon and the Banana River forms a relict cape aligned with False Cape (White, 1958; 1970). Multiple dune ridges apparently represent successive stages in this growth. Brooks (1972) suggested that the geologic history of the Merritt Island-Cape Canaveral barrier island was complex. The western portion of Merritt Island is substantially older than the east (Brooks, 1972; Clapp 1987). Erosion has reduced the western side to a nearly level plain (Brown et al., 1962).

The Atlantic Coastal Ridge extends along the east coast of Florida (White, 1970) and is a major feature of the mainland of Brevard County (Brown et al., 1962). White (1970) considered it to be made of both single and multiple relict beach ridges. The distribution of scrub soils along the Atlantic Coastal Ridge (Huckle et al., 1974; Fig. 1) depicts these multiple

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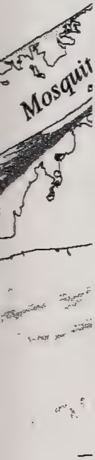

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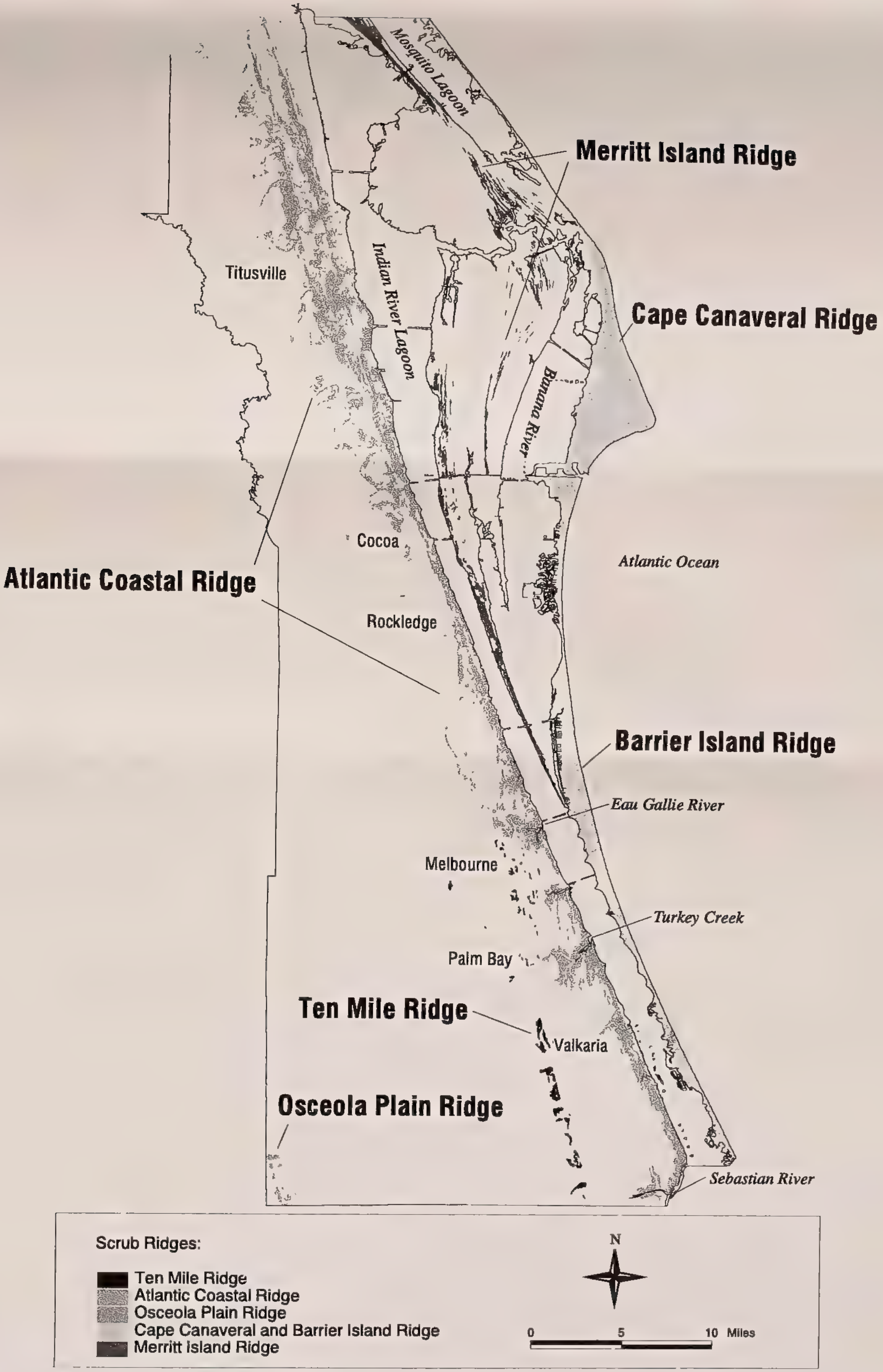

FIG. 1. Distribution of scrub ridge systems in Brevard County. Distribution is based on geomorphology (White, 1970) and soils maps (Huckle et al., 1974). Scrub soils are as in Appendix 1. The Ten Mile Ridge is defined only south of the Eau Gallie River. Discontinuities in scrub ridges have resulted from urbanization, where soils are mapped as urban land.

ridges, particularly in the north of the county. These ridges appear to have formed primarily along an erosional rather than prograding shoreline and in most places contain few carbonates. The ridge system is more complex and expansive in the vicinity of creeks like the Eau Gallie River, Turkey Creek, and the Sebastian River (Fig. 1). Formation of the Atlantic Coastal Ridge is associated with the Pamlico time (ca. 140,000-120,000 yr B.P., Bader and Parkinson [1990]) when sea level was about 9 m higher than present (White, 1970).

White (1970) reported that the Ten Mile Ridge branches off the Atlantic Coastal Ridge a few miles north of Eau Gallie and slowly diverges from it toward the west. Examination of the soils map (Huckle et al., 1974; Fig. 1) shows that the northern end of the Ten Mile Ridge originates in this location, but it also portrays extensive connectivity between the Ten Mile Ridge and the Atlantic Coastal Ridge at this point of divergence, especially around Horse Creek and the Eau Gallie River. Therefore, in this paper we differentiate the Atlantic Coastal Ridge and the Ten Mile Ridge south of the Eau Gallie River (Fig. 1). The Ten Mile Ridge is flatter than the Atlantic Coastal Ridge and appears to have formed during a pre-Pamlico high sea level (White, 1970).

A fifth scrub ridge is of minor extent in Brevard County and is poorly known. It occurs in the southwest corner of the county west of the St. Johns River Valley near the Osceola County line. This low ridge is associated with the scarp slope where the Osceola Plain descends to the St. Johns River Valley (White, 1958; 1970). This ridge does not appear to be named in previous reports, although it is clearly visibly in the soils map (Huckle et al., 1974; Fig. 1); we term it the Osceola Plain Ridge here. Other, similar ridges occur westward in Osceola and Orange counties along the drainage divide between the St. Johns and Kissimmee Rivers; these all are thought to be relict coastal features (White, 1958; 1970).

Soils associated with scrub formations in Brevard County—Scrub vegetation is restricted to soils associated with the geologic ridges discussed above. Ridge soils are derived from siliceous sands that originated from erosional processes in the Appalachian and Piedmont regions and moved south by longshore drift, and carbonate shell material of local origin (Davis, 1997; Scott, 1997). Ten soil series are associated with scrub in Brevard County (Appendix 1). Most scrub soils in Brevard are Entisols (Table 1), indicating little development of soil horizons, but Pomello sand is a Spodosol and Cocoa sand is an Alfisol. The distribution and abundance of these soils differ among scrub landscapes in the county (Table 2). Primary factors of soil formation are climate, parent material, topography, organisms, and time (Jenny, 1941; 1980). Scrub soils in Brevard County have experienced similar climate. They had similar origins as coastal dune deposits, although the amount of carbonate shell material may have differed initially. However, time and topography are the factors differing most among scrub landscapes.

TABLE 1. Classification of scrub soil series in Brevard County (Huckle et al., 1974).

Series	Family	Subgroup	Order
Astatula	Hyperthermic, uncoated	Typic quartzipsamment	Entisol
Canaveral	Mixed, hyperthermic	Aquic udipsamment	Entisol
Cocoa	Sandy, siliceous, hyperthermic	Psammentic hapludalf	Alfisol
Orsino	Hyperthermic, uncoated	Spodic quartzipsamment	Entisol
Palm Beach	Carbonitic, hyperthermic	Typic udipsamment	Entisol
Paola	Hyperthermic, uncoated	Spodic quartzipsamment	Entisol
Pomello	Sandy, siliceous, hyperthermic	Arenic haplohumod	Spodosol
St. Lucie	Hyperthermic, uncoated	Typic quartzipsamment	Entisol
Taveres	Hyperthermic, uncoated	Typic quartzipsamment	Entisol
Welaka	Hyperthermic, uncoated	Spodic quartzipsamment	Entisol

TABLE 2. Distribution of scrub soil series across scrub landscapes in Brevard County. Area is in hectares (ha); percentages are of soil series within a ridge. Data were derived by overlaying ridge boundaries and scrub soil polygons from the soil survey (Huckle et al., 1974) into a GIS coverage. Areas developed into urban land or quartzipsamments at the time of the soil survey were excluded.

Soil type	Cape Canaveral & Barrier Island	Merritt Island	Atlantic Coastal Ridge	Ten Mile Ridge	Osceola Plain Ridge
Excessively well-drained					
Astatula	0	360 11.8%	1819 14.4%	0	0
Palm Beach	2075 26.8%	8 0.3%	0	0	0
Paola	9 0.1%	731 24.0%	3900 31.0%	2 0.1%	0
St. Lucie	0	10 0.3%	1149 9.1%	0	0
Well-drained					
Cocoa	0	394 12.9%	374 3.0%	0	0
Tavares	9 0.1%	220 7.2%	0	0	0
Welaka	1167 15.1%	0	0	0	0
Moderately well-drained					
Canaveral	4252 54.9%	83 2.7%	401 3.2%	0	0
Orsino	0	113 3.7%	422 3.4%	422 41.9%	0
Pomello	235 3.0%	1125 37.0%	4525 35.9%	583 58.0%	109 100.0%
Total	7747	3044	12590	1007	109

Cape Canaveral and the outer barrier island have the youngest soils. Well-drained soils there are in the Palm Beach, Canaveral, and Welaka series, and these soils cover much of the landscape (Table 2). Palm Beach and Canaveral soils retain shell fragments in the upper horizons and are alkaline. The older Welaka soil lacks shells fragments in the upper horizons but retains them at depth; it is acid near the surface and neutral to alkaline at depth. Shell fragments influence soil nutrient levels, particularly calcium and magnesium, as well as pH.

On the eastern half of Merritt Island, well-drained scrub soils are distributed along former dunes, separated by poorly-drained flatwoods or swale marshes (Huckle et al., 1974). The ridges are low, usually about 3.0–3.7 m in elevation. Paola and Astatula are the best drained series, and there are smaller areas of Cocoa and Orsino soils, but the moderately well-drained Pomello sand is the most abundant scrub soil (Table 2; Schmalzer and Hinkle, 1990b). These are all acid, sandy soils except for the sandy, but circumneutral Cocoa series, that formed over coquina. Although Cape Canaveral and Merritt Island have similar origins, the greater age of Merritt Island has allowed for leaching of shell material from most soils. Areas that are primarily flatwoods and mapped as Immokalee or Myakka soil may have small ridges that support scrub vegetation on better drained soils; soils of these small ridges have not been mapped separately (Duncan et al., 1996). The western half of Merritt Island primarily contains poorly-drained soils (Huckle et al., 1974), reflecting its lower topography and greater age.

The Atlantic Coastal Ridge contains substantial areas of the well-drained Paola, St. Lucie, and Astatula soils on high ridges, up to ca. 15 m elevation, but the moderately well-drained Pomello series is also common (Table 2). Some ridges are underlain by coquina and have Cocoa soils.

On the older, lower Ten Mile Ridge, Pomello and Orsino soils occur on the higher areas in a matrix of poorly-drained flatwoods and marshes (Table 2). The Osceola Plain Ridge has Pomello soils in a flatwoods matrix (Table 2).

Mapped soil types often include small areas of other soils. Areas mapped as well-drained scrub soils may contain inclusions of poorly-drained soils that do not support scrub vegetation. Similarly, scrub soils and vegetation may occur as better drained inclusions within areas mapped as poorly-drained soils.

Scrub soils in Table 2 (24,497 ha) did not necessarily support native scrub vegetation even when mapped in 1974. Subsequent urban and agricultural development have further reduced scrub vegetation on the ridges.

The scrub ecological community and landscape in Brevard County—Paleoecology and history of scrub—The communities and landscapes that constitute scrub in Brevard County have been shaped in part by the paleoecology and history of scrub. The dynamic geologic history of Florida produced changing landscapes in Brevard County. These changing landscapes and possible climatic changes resulted in changing vegetation patterns throughout the Pleistocene and Holocene. The vegetation pattern that occurred at the time of European settlement had been in place for probably not more than 5,000 years. These changes from glacial to post-glacial conditions in Florida are best documented from a series of lakes in the center of the state where pollen records from cores have been obtained (Watts, 1969; 1971; 1975; 1980; Watts and Stuvier, 1980; Watts and Hansen, 1988; Watts et al., 1992; Grimm et al., 1993).

Sea-level decline during glacial periods, perhaps combined with reduced precipitation, resulted in a regional decline in water table of at least 26 m at 18,000–15,000 yr B.P. (Watts and Hansen, 1988). Water table levels rose thereafter with many lakes filling about 8,500 yr B.P. and extensive swamping about 5,000 yr B.P. (Watts and Hansen, 1988). Only very deep lakes preserve sediment records of the period of maximum water table decline.

Early glacial vegetation is recorded from Lake Annie (Watts, 1975) and Lake Tulane (Watts and Hansen, 1988) on the Lake Wales Ridge. At Lake Annie, a xerophytic vegetation of Florida rosemary, jointweed (*Polygonella* spp.), herbs, and scrub oaks occurred between 37,000 and 13,000 yr B.P.; this was followed by an oak woodland or scrub with prairie patches between 13,000 and 4,700 yr B.P. Modern vegetation dominated by pine with swamp and bayhead species is recorded after 4,700 yr B.P. Lake Tulane underwent a series of oscillations between pine forest and oak woodland or savanna (Grimm et al., 1993).

In northern Florida, a somewhat different pattern is recorded. An open pine forest dominated around Sheelar Lake near Gainesville between 24,000 and 18,500 yr B.P. (Watts and Stuvier, 1980). There was a gap in the record until 14,600 yr B.P. when a dry oak-hickory forest occurred. Mesic trees increased between 14,000–13,000 yr B.P. then decreased, while pine increased to 11,200 yr B.P. and dominated to 9,500 yr B.P. A xeric oak scrub or woodland with prairie occurred from 9,500 to about 7,200 yr B.P., after which the modern vegetation pattern of pine forests and swamps gradually established (Watts and Stuvier, 1980). At some other sites, widespread oak scrub or woodland persisted to about 5,000 yr B.P. (Watts, 1969; 1971).

Fires in Florida occurred throughout the record as indicated by charcoal in sediment cores, but fire frequency varied (Watts and Hansen, 1988). Changes in both climate and vegetation pattern would have affected fire frequency.

Comparable paleoecological records are generally unavailable for coastal regions such as Brevard County; however, the development of extensive swamps in Florida approximately corresponds to the filling of the Indian River Lagoon (Bader and Parkinson, 1990). We can reconstruct a likely sequence of changes in the landscape. During glacial periods, scrub and other xerophytic vegetation would have been widespread due to lower water tables. Scrub would have occurred on the active barrier islands, offshore their present location. With the rapid increase in sea level from deglaciation, coastal scrub retreated or was inundated. As the barrier islands assumed their present form, scrub established or persisted on well-drained sites. On the mainland, changes would have been more gradual, because the increase in regional water tables lagged sea level rise. Scrub became restricted to high ridges as water tables rose. The pre-settlement pattern of vegetation dates from about 5,000 yr B.P.

Scrub and related community types in Brevard County—The major scrub community types are not uniformly distributed among the five scrub landscapes: Cape Canaveral, Merritt Island, Atlantic Coastal Ridge, Ten Mile Ridge, and Osceola Plain Ridge (Table 3). Florida scrub is often defined as a high, dry habitat found on white, sandy soils, but scrub landscapes represent a diverse mosaic of habitats (Myers, 1990; Abrahamson and Hartnett, 1990). Native scrub communities often occur as patches within a matrix of poor-to moderately-drained flatwoods and isolated wetlands (Breininger et al., 1988; 1991). The different communities within the scrub landscapes in Brevard County are identified below.

Sand pine scrub—Sand pine scrub has a closed to scattered canopy of sand pine and an understory of scrub oaks (*Quercus myrtifolia, Q. geminata, Q. chapmanii*), saw palmetto (*Serenoa repens*), rusty lyonia (*Lyonia ferruginea*), and other shrubs. Florida rosemary may occur. Sand pine scrub long has been recognized as a distinctive vegetation type (Laessle, 1942; Myers, 1990). In Brevard County, sand pine scrub is found primarily on the mainland on higher ridges of the Atlantic Coastal Ridge (Table 3); only minor areas occur on Merritt Island (Provancha et al., 1986) or Cape Canaveral (Provancha, 1988). Soils of sand pine scrub in Brevard County are typically excessively-drained Paola or St. Lucie sands (Huckle et al., 1974). Some sand pine scrub occurs on the well-drained Cocoa sand on sandy ridges underlain by coquina (Huckle et al., 1974). Some of the extensive areas of sand pine are associated with larger creeks (e.g., Crane Creek, Eau Gallie River, Sebastian River, Turkey Creek) that would have altered fire spread through the pre-settlement landscape (Swain et al., 1995). Abrahamson and co-workers (1984) recognized two phases of sand pine scrub on the southern Lake Wales Ridge (at Archbold Biological Station); these had either predominantly evergreen oaks or Florida rosemary as the shrub layer. A distinct Florida rosemary phase of sand pine scrub appears absent from Brevard County, although Florida rosemary occurs with oaks in many sand pine scrub stands. Reduced fire frequency has allowed sand pine to spread from the high ridges into oak-saw palmetto scrub and scrubby flatwoods.

Rosemary scrub—Rosemary scrub (rosemary bald) is typically an open shrubland dominated by Florida rosemary with numerous open, sandy areas (Myers, 1990). Rosemary scrub occurs on higher ridges of the southern Lake Wales Ridge; however, Abrahamson and co-workers (1984) included rosemary scrub with and without a sand pine canopy in their sand pine scrub-

TABLE 3. Scrub community types across scrub landscapes in Brevard County. Area in hectares (ha). These are estimates derived from a wide variety of sources with data collected in different years.

	Cape Canaveral & barrier island		Merritt Island				
Community type	CCAS[1]	Barrier Island[4]	Merritt Island[2] Federal	Merritt Island non-Federal	Atlantic Coastal Ridge	Ten Mile Ridge	Osceola Plain Ridge[3]
Sand Pine Scrub	3.6	6.6	8.4	14.9	1180.0	82.0	absent
Rosemary Scrub	minor	absent	absent	absent	minor	absent	absent
Oak & Oak-Saw Palmetto Scrub	325.2	84.8	909.2	62.3	1585.0	131.0	present
Scrubby Flatwoods	64.0	2.9	286.4	57.7	1671.0	379.0	present
Coastal Strand & Scrub	2503.9	288.1	355.2	absent	absent	absent	absent
Depression Marshes	present[5]	minor	common	common	common	common	present
Total scrub area	2896.7	382.4	1559.2	134.9	4436.0	592.0	109.0
Source	Swain and Larson (1991), Provancha (1987, 1988), and this paper	Swain and co-workers (1995)	Provancha and co-workers (1986), Provancha (1987), and this paper	Swain and co-workers (1995)	Swain and co-workers (1995) and this paper	Swain and co-workers (1995) and this paper	Aerial photography; soils map

[1] To estimate scrub on CCAS, a landuse coverage by Swain and Larson (1991) was overlaid with a soil coverage by Provancha (1987). Scrub occurring on Welaka soil was classified as oak-saw palmetto scrub, and scrub occurring on Canaveral and Palm Beach soil was classified as coastal scrub.

[2] Scrub occurring on Merritt Island Federal property was classified by overlaying a vegetation coverage (Provancha et al., 1986) and a soils coverage (Provancha, 1987). Only scrub or scrubby flatwoods occurring on soils identified in Appendix 1 was included. Disturbed scrub identified by Provancha and co-workers (1986) on Merritt Island Federal property was not included here.

[3] No vegetation map was available for the Osceola Plain Ridge; these data are estimates based on the soils coverage and do not necessarily represent scrub vegetation present.

[4] South of CCAS.

[5] Common historically.

rosemary phase type. Rosemary scrub is not well developed in Brevard County. Some areas occur on Cape Canaveral (Stout, 1980). Rosemary is associated with sand pine scrub and some oak scrub on the Atlantic Coastal Ridge, but areas dominated by rosemary are rare (Table 3).

Oak scrub and oak-saw palmetto scrub—Oak scrub is a shrubland dominated by scrub oaks (*Quercus myrtifolia, Q. geminata, Q. chapmanii*). Associated species may include saw palmetto, Florida rosemary, scrub hickory (*Carya floridana*), and rusty lyonia. Soils include the excessively-drained series that may support sand pine scrub or better drained inclusions within moderately well-drained soil series. Oak scrub occurs on the higher ridges of Merritt Island (Schmalzer and Hinkle, 1987; 1992b), on the Atlantic Coastal Ridge, and on some interior sections of the barrier islands including Cape Canaveral (Schmalzer and Boyle, unpublished).

Oak-saw palmetto scrub is a shrubland dominated by scrub oaks (*Quercus myrtifolia, Q. geminata, Q. chapmanii*), saw palmetto, and ericaceous shrubs including *Lyonia ferruginea, L. fruticosa, L. lucida,* and *Befaria racemosa.* Shiny blueberry (*Vaccinium myrsinites*) is a common small shrub, and wiregrass (*Aristida stricta*) a frequent herb. *Sabal etonia* and *Quercus inopina* that are important in scrub of the Lake Wales Ridge (Abrahamson et al., 1984) do not occur in Brevard County. Soils are typically moderately well-drained Pomello or Orsino sands (Huckle et al., 1974). Oak-saw palmetto scrub may occur on better drained areas or inclusions of better drained soils within poorly-drained flatwoods soils such as Immokalee sand. Oak-saw palmetto scrub is well represented on Merritt Island (Schmalzer and Hinkle, 1987; 1992b). Oak and oak-saw palmetto scrub are considered together for the remainder of this paper.

Myers (1990) included oak scrub in his discussion of scrub communities. Abrahamson and co-workers (1984) and Abrahamson and Hartnett (1990) include oak and oak-saw palmetto scrub with scrubby flatwoods. Oak scrub, oak-saw palmetto scrub, and scrubby flatwoods occupy intermediate positions along the gradient between xeric scrub and mesic flatwoods (Laessle, 1942; Abrahamson et al., 1984; Abrahamson and Hartnett, 1990; Schmalzer and Hinkle, 1992b). On some landscapes, including Brevard County, these communities occupy more of the landscape than sand pine scrub.

Scrubby flatwoods—Scrubby flatwoods have a shrub layer of oak-saw palmetto scrub but an open canopy of pines. On Merritt Island, slash pine (*Pinus elliottii* var. *densa*) is the canopy species (Schmalzer and Hinkle, 1985; Breininger et al., 1988). On the mainland, slash pine and longleaf pine (*Pinus palustris*) both occur. Soils are similar to those of oak-saw palmetto scrub.

Sandhill—Sandhill or high pine vegetation was common on well-drained soils in Florida and the southeastern coastal plain before settlement (Myers, 1990; Stout and Marion, 1993; Ware et al., 1993). It was characterized by an open canopy of longleaf pine with a understory of wiregrass and scattered turkey oak (*Quercus laevis*). At the southern end of the Lake Wales Ridge, a variant of sandhill had South Florida slash pine (*Pinus elliottii* var. *densa)* as the canopy species (Abrahamson et al., 1984). Sandhill has been greatly reduced from its original status (Myers, 1990; Ware et al., 1993). It is unclear how abundant sandhill was historically in Brevard County. Elements of sandhill flora persist, as for example along U.S. 1 in the Eau Gallie region, but sites that resemble sandhill community composition and structure are rare. Small areas in the south of the county near the C-54 canal may represent this community (Snodgrass et al., 1991). Small patches of Brevard County scrub on "yellow" sands, such as the Cocoa and Orsino series, particularly in the Titusville and Rockledge area, frequently have scrub hickory and may be related to the Southern Ridge Sandhill hickory phase described by Abrahamson and co-workers (1984).

Xeric hammock—Xeric hammock is a low stature forest with a canopy of tree-size scrub oaks and a shrub layer of saw palmetto. Other scrub shrubs that may reach tree size include scrub hickory, rusty lyonia, and wild olive (*Osmanthus americana*). Epiphytic lichens and ball moss (*Tillandsia recurvata)* may occur. Xeric hammock occurred historically where natural firebreaks limited the spread of fire (Myers, 1990), but its extent in Brevard County has been increased by fire suppression and landscape fragmentation.

Coastal strand and coastal scrub—Coastal strand is a shrub community on the barrier island on recent dunes inland from the coastal dunes (sea oats [*Uniola paniculata*] zone). Saw palmetto, sea grape (*Coccoloba uvifera*), wax myrtle (*Myrica cerifera*), nakedwood (*Myrsianthes fragrans*), tough buckthorn (*Bumelia tenax*), and rapanea (*Rapanea punctata*) are typical shrubs (Schmalzer and Hinkle, 1985; Johnson et al., 1990). On the "South Beaches" part of the barrier island, i.e., south of Melbourne Beach, other tropical shrubs such as fiddlewood (*Citharexylum fruticosum*) become frequent. Shrubs may be dense or sandy openings may be common. If open, herbs such as dune sunflower (*Helianthus debilis*) and camphorweed (*Heterotheca subaxillaris*) often occur. Pruning of shrubs by salt spray is common. Soils are typically the excessively well-drained Palm Beach sand or the moderately well-drained Canaveral sand (Huckle et al., 1974). Coastal strand is best represented on KSC (Provancha et al., 1986) and Cape Canaveral Air Station (CCAS) (Provancha, 1988). Outside of Federal property, some remnants persist (Johnson et al., 1990; Swain et al., 1995).

Coastal scrub is a shrub community on the barrier island inland from coastal strand where oaks become co-dominant or dominant (Johnson and Barbour, 1990). The oak is often a coastal form of live oak (*Quercus virginiana*) (Kurz, 1942; Johnson et al., 1990). Other shrubs include saw palmetto, wax myrtle, tough buckthorn, rapanea, and Florida privet (*Forestiera* *segregata*) (Schmalzer and Hinkle, 1985). The soil is typically the moderately well-drained Canaveral sand (Huckle et al., 1974). Unlike soils of inland scrub, this soil is alkaline and still retains shell fragments in the upper horizons. Coastal scrub is best represented on CCAS and some sections of the outer barrier island part of KSC. Outside of Federal property most has been developed, but some remnants persist (Johnson et al., 1990). Coastal strand and scrub are habitat for several rare plants including *Cereus gracilis* var. *simpsonii, Glandularia maritima, Lantana depressa* var. *floridana,* and *Tephrosia angustissima* var. *curtissii.* Coastal strand and scrub are considered together for the remainder of this paper.

Swale or depression marshes—Freshwater marshes are an integral part of scrub landscapes; these marshes form in swales between scrub ridges or in depressions. For example, a variety of swale marshes and seasonal ponds occur on the southern Lake Wales Ridge (Abrahamson et al., 1984). Plant species composition varies with marsh size and hydrology. These isolated wetlands serve as breeding ponds essential for many of the scrub herpetofauna, such as the threatened Florida gopher frog (*Rana capito aesopus*) (Moler and Franz, 1987). Amphibians, originating from these wetlands, form a significant portion of the food chain, especially for species such as the eastern indigo snake (*Drymarchon corias couperi*) (Moler and Franz, 1987). Gopher tortoises (*Gopherus polyphemus*) with burrows in well-drained areas may find more food available in swale marshes or mesic flatwoods than in well-drained scrub (Breininger et al., 1988; 1994). Some bird species also use these marshes (Breininger, 1992a).

Scrub landscapes in Brevard County—Scrub community types are associated on several scrub landscapes in Brevard County that have different features (Table 3). Quantification of these scrub landscapes was conducted by Provancha (1988) for the federal lands on Cape Canaveral Air Station, and Provancha and co-workers (1986) for John F. Kennedy Space Center including Merritt Island National Wildlife Refuge (MINWR), and Canaveral National Seashore (CNS). These federal lands comprise the great majority of the remaining scrub on Merritt Island and Cape Canaveral. The analysis of scrub community types on Cape Canaveral and Merritt Island was based on color-IR aerial photo interpretation, groundtruthing, and digitizing into ERDAS (Provancha et al., 1986). These studies classified Merritt Island and Cape Canaveral scrub as: coastal strand, sand pine scrub, mixed oak-saw palmetto scrub (which includes some areas that are predominantly a more mesic saw palmetto-lyonia community), disturbed oak-saw palmetto scrub, and slash pine flatwoods (which includes both mesic and scrubby flatwoods). For the purposes of comparison with other county-wide mapping efforts, we subdivided this classification by overlaying the Provancha and co-workers (1986) vegetation coverage over a soil type coverage to estimate acreage of oak scrub and scrubby flatwoods within the mixed oak-saw palmetto and slash pine flatwoods classes.

Snodgrass and co-workers (1991) and Swain and co-workers (1995) conducted similar scrub mapping for the non-federal properties on the Atlantic Coastal Ridge, the Ten Mile Ridge, and the barrier island south of CCAS. Aerial photo interpretation and ground surveys of scrub on the Atlantic Coastal Ridge, the Ten Mile Ridge, and the barrier island south of CCAS were conducted in 1993-1994 by Swain and co-workers (1995). They used two existing GIS coverages with information on the distribution of scrub habitats in Brevard developed by Snodgrass and co-workers (1991) and by Swain and Larson (1991) (Swain et al., 1995). These coverages were reviewed with additional photo interpretation and groundtruthing to: (a) confirm the existence of scrub throughout each polygon; (b) determine which polygons had been cleared or partially cleared; (c) interpret the scrub type for each polygon (sand pine scrub, xeric oak scrub, scrubby flatwoods, and coastal scrub); and (d) add in any polygons of scrub omitted from these two original coverages. This map included municipalities and areas with more than 20% "build-out" (i.e., 20% of the landscape already developed) not mapped by Snodgrass and co-workers (1991).

Cape Canaveral—Cape Canaveral is a large, geologically-recent barrier island with predominantly well-drained soils. Coastal strand and coastal scrub are the predominant types with oak scrub inland (Table 3). Mesic hammocks occur near the Banana River. Kurz (1942) discussed the relationship between coastal strand, coastal scrub, and inland scrub. On Cape Canaveral, he noted the transition between shrublands dominated by saw palmetto and other shrubs seaward (i.e., coastal strand) and those with increased oak cover on more inland dunes (i.e., coastal scrub). On alkaline soils, the oak present was a dwarf form of live oak he termed Rolf's oak (*Q. rolfsii* see Small, 1933). On more inland sites with older, leached but still circumneutral soils, he found scrub with sand live (*Q. geminata*), myrtle (*Q. myrtifolia*), and Chapman oaks (*Q. chapmanii*), tallowwood (*Ximenia americana*), and blueberry (*Vaccinium* sp.) (i.e., oak scrub). Recent data indicate that coastal scrub is associated with the Palm Beach and Canaveral soil series and oak scrub with the Welaka series (Schmalzer and Boyle, unpublished). Remaining swale marshes on Cape Canaveral are predominantly *Muhlenbergia capillaris* with some sand cordgrass (*Spartina bakeri*) and sawgrass (*Cladium jamaicense*) (Schmalzer, Pers. Observ.).

Cape Canaveral Air Station has been Air Force property since the 1950s. Some scrub on CCAS has been lost to military development. There also appears to have been substantial loss of swale marshes. Vegetation of CCAS includes about 2,897 ha of scrub (Table 3). Coastal scrub is most abundant (79.6%), and oak-saw palmetto is next in abundance at 10.5% (Table 3). There are minor amounts of scrubby flatwoods and sand pine scrub on

CCAS (Table 3). Much scrub has been unburned for >30 years and has developed xeric hammock features (Schmalzer and Boyle, unpublished).

North of CCAS, the barrier island separating Mosquito Lagoon from the Atlantic Ocean lies within KSC and Canaveral National Seashore. The barrier island becomes narrow; coastal dunes, coastal strand, and wetlands comprise most of the vegetation (Provancha et al., 1986).

South of CCAS within Brevard County, the barrier island narrows. The vegetation pattern was somewhat similar to CCAS with coastal strand, scrub, hammocks, and wetlands. Oak-saw palmetto or sand pine scrub occurred historically in some localities (e.g., south of the Eau Gallie Boulevard) where the barrier island was broader (Schmalzer, Pers. Observ.). Development has been intensive on the barrier island south of CCAS, with only remnants of coastal strand and scrub persisting (Johnson et al., 1990). Very few patches of scrub remain from Cocoa Beach south to Melbourne Beach, but from Melbourne Beach south to Sebastian Inlet, there are some larger remaining fragments. Most (94%) of the limited coastal scrub outside federal properties is within this area (Fig. 1, Table 3).

Merritt Island—Merritt Island is older, lower topography than Cape Canaveral with more of the landscape in poorly-drained soils (Huckle et al., 1974; Schmalzer and Hinkle, 1990b). The northern part of Merritt Island is within John F. Kennedy Space Center of the National Aeronautics and Space Administration (NASA). NASA development has removed some scrub and fragmented some, but most of KSC is managed as Merritt Island National Wildlife Refuge by the U. S. Fish and Wildlife Service.

The dune-swale topography of eastern Merritt Island (within KSC) supports oak-saw palmetto scrub or scrubby flatwoods on higher ridges and wetlands vegetation, frequently marshes, in the swales. Species composition of the scrub varies along a depth to water table gradient with oaks dominant on drier sites and saw palmetto dominant on wetter sites (Schmalzer and Hinkle, 1987; 1992b; Breininger et al., 1988). Structural characteristics and biomass change with time since fire, but dominant species persist (Schmalzer and Hinkle, 1992a; 1996). The intervening marshes vary in size, topography, hydrology, and vegetation. Some display zonation patterns, while others are more uniform. Types include beardgrass (*Andropogon* spp.), sand cordgrass, sawgrass, and maidencane (*Panicum hemitomon*) (Schmalzer and Hinkle, 1985). Numerous other wetland plants occur. In the central and southern part of KSC, shallow swales in scrubby and mesic flatwoods support Curtiss' sand reedgrass (*Calamovilfa curtissii*) (Schmalzer and Hinkle, 1985; 1990a), a rare species with disjunct populations in the Florida Panhandle and Merritt Island (Johnson and Blyth, 1988; Johnson, 1993). With fire exclusion or hydrologic alteration, swale or depression marshes are often subject to invasion by woody shrubs such as wax myrtle, Carolina willow (*Salix caroliniana*), and groundsel (*Baccharis* spp.) (Duncan et al., 1996).

The western half of Merritt Island is flatter and lacks ridge-swale topography. It is a matrix of flatwoods, marshes, and hammocks. Some better drained areas support oak-saw palmetto scrub or scrubby flatwoods.

The vegetation map of KSC (1:9,600) (Provancha et al., 1986) estimated that 6,830 ha of scrub occur on KSC; this included oak-saw palmetto scrub and saw palmetto-lyonia shrubland (Schmalzer and Hinkle, 1985). Saw palmetto-lyonia shrub vegetation is on poorly-drained soils and is not included in the scrub types discussed in this paper. Here, we estimate 909.2 ha of oak-saw palmetto scrub within KSC in Brevard County (Table 3). Only minor areas (8.4 ha) of sand pine scrub occur. Slash pine flatwoods occupy 5,011 ha (Provancha et al., 1986) and vary in canopy density and understory composition. Based on an overlay analysis with xeric soils, only 5.7% of these flatwoods were scrubby flatwoods (286.4 ha, Table 3) occurring on drier sites with an understory of scrub oaks, saw palmetto, ericaceous shrubs, and wiregrass. On wetter sites, saw palmetto, gallberrry holly (*Ilex glabra*), and *Lyonia lucida* are dominant shrubs. Coastal strand and scrub occupies about 355 ha on KSC; these types occur primarily in the False Cape area and on the barrier island separating Mosquito Lagoon and the Atlantic Ocean.

On Merritt Island outside of KSC, most original scrub has been removed by development (Swain et al., 1995). The limited scrub (135 ha) remaining on Merritt Island, outside federal properties, was half scrubby flatwoods and half oak scrub (Table 3).

Atlantic Coastal Ridge—The aerial photo interpretation and ground surveys conducted by Swain and co-workers (1995) in 1993-1994 documented 4,436 ha of scrub remaining on the Atlantic Coastal Ridge in mainland Brevard County (Table 3). The Atlantic Coastal Ridge is the highest, best drained topography in Brevard County with the greatest proportion of excessively-drained scrub soils (Table 2). Sand pine scrub or oak scrub occupy the remaining, undeveloped, higher sections of the ridge with oak-saw palmetto scrub or scrubby flatwoods on the slopes. Depression marshes occur in low areas. Surrounding native vegetation is primarily flatwoods or hammocks (Boyle, 1996). The majority of the remaining scrub is either scrubby flatwoods (38%) or oak scrub (36%) (Table 3), although a substantial amount of the remaining scrub is sand pine over an oak understory (26%), a result of 20–50 years of fire suppression. Scrub on the Atlantic Coastal Ridge is distributed in three main areas: 26% south of Melbourne; 16% between Melbourne and Cocoa, and 58% north of Cocoa. The proportion of each scrub type along the Atlantic Coastal Ridge varied from south to north. South of Melbourne, the Atlantic Coastal Ridge is dominated by scrubby flatwoods (32%) and sand pine scrub (45%). The scrubby flatwoods were concentrated north and south of the Valkaria Airport. Sand pine scrub south of Melbourne is often associated with the margins of larger creeks draining into the Indian River Lagoon, such as Turkey Creek, and the Sebastian River; this may have been a result of a fire shadow effect along these creeks.

Between Melbourne and Cocoa, the Atlantic Coastal Ridge supports predominantly scrubby flatwoods (>50%), and the major stands of scrub in this area are found east of the new town of Viera (Swain et al., 1995). North of Cocoa, the Ridge supports oak scrub (48%) and scrubby flatwoods (36%) with major scrub centers around the TICO Airport in the City of Titusville, and in the Fox Lake-South Lake region. In all areas of the Atlantic Coastal Ridge, scrub has been fragmented into small polygons. Over half of remaining scrub polygons are <2 ha, although these only constituted 8% of the remaining scrub (Swain et al., 1995).

Ten Mile Ridge—The Ten Mile Ridge in the southern part of Brevard County is an older, lower ridge than the Atlantic Coastal Ridge, and diverges from the Atlantic Coastal Ridge in the Eau Gallie-Melbourne area (Fig. 1). The Ridge is now discontinuous through the City of Palm Bay, where virtually all the original scrubby flatwoods have been lost and remaining scattered scrub patches are primarily <1 ha in size (Swain and Schmalzer, Pers. Observ.). South of Palm Bay, the remaining sections of the Ten Mile Ridge generally have scrubby flatwoods or oak-saw palmetto scrub (510 ha, Table 3) on the higher areas in a matrix of mesic flatwoods, depression marshes, and other wetlands. Some areas on the Ten Mile Ridge were large, undeveloped ranchlands that were burned for range management and retained much of their native habitat structure. The scrub on the Atlantic Coastal Ridge west of Fox Lake-South Lake west of Titusville appears to be similar to that of the Ten Mile Ridge.

Osceola Plain Ridge—Although the Osceola Plain Ridge has not been systematically ground-surveyed, a review of available aerial photography, and an aerial survey by local natural resources staff (Robinson, 1995), suggests it resembles the Ten Mile Ridge, with oak-saw palmetto scrub or scrubby flatwoods in a matrix of flatwoods and marshes. Surrounding landuse appears to be agricultural.

Distribution of rare scrub species in Brevard County—Scrub is known for its abundance of endemic and often rare vascular plants; many of these species are restricted to the older, inland scrub ridges, particularly the Lake Wales Ridge (Christman and Judd, 1990). Several rare plants (listed by the U.S. Fish and Wildlife Service or that were previously candidate species for listing) occur or once occurred in scrub of Brevard County. These species are distributed differently across scrub landscapes in the county (Table 4). Five species, *Cereus gracilis* var. *simpsonii, Chamaesyce cumulicola, Glandularia maritima, Lantana depressa* var. *floridana,* and *Tephrosia angustissima* var. *curtissii,* are known only from the outer barrier island or Cape Canaveral. *Lechea divaricata* and *Pteroglossaspis ecristata* occur on Merritt Island and the Atlantic Coastal Ridge. *Conradina grandiflora* occurs on the Atlantic Coastal Ridge and the Ten Mile Ridge, but is absent from the outer

TABLE 4. Distribution of rare scrub plants across scrub landscapes in Brevard County[1].

Species	Cape Canaveral & Barrier Island	Merritt Island	Atlantic Coastal Ridge	Ten Mile Ridge
Cereus gracilis var. *simpsonii* (Prickly apple)	present	absent	absent	absent
Chamaesyce cumulicola (Sand dune spurge)	present	absent	absent	absent
Conradina grandiflora (Large-flowered rosemary)	absent	absent	present	present
Dicerandra thinicola	absent	absent	present	absent
Glandularia maritima (Coastal vervain)	present	absent	absent	absent
Lantana depressa var. *floridana* (Atlantic Coast Florida lantana)	present	absent	absent	absent
Lechea cernua (Nodding pinweed)	present	present	present	unknown
Lechea divaricata (Pine pinweed)	absent	present	present	unknown
Pteroglossaspis ecristata (False coco)	absent	present	present	unknown
Schwalbea americana[2] (American chaffseed)	absent	absent	absent	absent
Tephrosia angustissima var. *curtissii* (Coastal hoary-pea)	present	absent	absent	absent
Warea carteri[3] (Carter's warea)	present	absent	absent	absent

[1] Occurrence of species on the Osceola Plain Ridge is unknown.
[2] Historical records only, no recent collections.
[3] One record, Spessard Holland Park on barrier island.

barrier island and Merritt Island. *Dicerandra thinicola* is restricted to a single area of the Atlantic Coastal Ridge in Titusville.

Cereus gracilis var. *simpsonii* (prickly apple, Cactaceae, Formerly Category 2) is a sprawling cactus of southeastern Florida that ranges north to Brevard County in coastal hammocks and scrub (Wunderlin, 1982). It once occurred at Turtle Mound in southern Volusia County (Norman, 1976) but is no longer there (Norman and Hawley, 1995) due to severe freezes. The "South Beaches" of Brevard County are now its northernmost location (Johnson et al., 1990).

Chamaesyce cumulicola (sand dune spurge, Euphorbiaceae, Formerly Category 2) is a prostrate, herbaceous species of coastal dunes and scrub (Wunderlin, 1982; Fernald, 1989) endemic to Florida (Mueller et al., 1989); it occurs on CCAS (Chafin et al., 1996) and the South Beaches (EELP, 1992a).

Glandularia maritima (coastal vervain, Verbenaceae, Formerly Category 2) is an herbaceous species of coastal counties (Wunderlin, 1982) endemic to Florida (Mueller et al., 1989). It occurs on the outer barrier island of KSC

(Poppleton et al., 1977; Johnson et al., 1990; Schmalzer and Hinkle, 1990a), on CCAS (Chafin et al., 1996), and in remnant coastal dunes and scrub of the South Beaches section of Brevard (Johnson et al., 1990; EELP, 1992a).

Lantana depressa var. *floridana* (Atlantic Coast Florida lantana, Verbenaceae, Formerly Category 2) is a small, Florida endemic shrub (Mueller et al., 1989) distributed along the east coast of Florida and also on the Lake Wales Ridge (Sanders, 1987); it occurs on CCAS (Chafin et al., 1996) and remnant coastal scrub of the South Beaches (Johnson et al., 1990; EELP, 1992a).

Tephrosia angustissima var. *curtissii* (coastal hoary-pea, Fabaceae, Formerly Category 2) is a typically decumbent herb of coastal dunes and scrub on the east coast of Florida (Wunderlin, 1982), endemic to the state (Mueller et al., 1989). Although reported from KSC (Sweet, 1976; Poppleton et al., 1977), it has not been observed there in recent years (Schmalzer and Hinkle, 1990a) but does occur in coastal dunes and scrub of the South Beaches (EELP, 1992a).

Lechea cernua (nodding pinweed, Cistaceae, Formerly Category 2) is endemic to Florida but widely distributed in xeric sites (Wilbur and Daoud, 1961; Wunderlin, 1982; Mueller et al., 1989). In Brevard, it is known from Cape Canaveral (Chafin et al., 1996), Merritt Island (Poppleton et al., 1977; Poppleton, 1981; Schmalzer and Hinkle, 1990a), and the Atlantic Coastal Ridge (Schmalzer, Pers. Observ.).

Lechea divaricata (pine pinweed, Cistaceae, Formerly Category 2) is endemic to Florida but widely distributed in xeric sites (Wilbur and Daoud, 1961; Wunderlin, 1982; Mueller et al., 1989). In Brevard, it is known from Merritt Island and the Atlantic Coastal Ridge (Schmalzer, Pers. Observ.).

Conradina grandiflora (large-flowered rosemary, Lamiaceae, Formerly Category 2) is a shrubby mint found along the east coast of Florida (Wunderlin, 1982; Austin et al., 1987; Fernald, 1989; Mueller et al., 1989) and known in Brevard County from the Atlantic Coastal Ridge and the Ten Mile Ridge in sand pine and oak scrub (Schmalzer, Pers. Observ.). It was once reported, apparently from the outer barrier island (Poppleton et al., 1977), but those populations no longer exist (Poppleton, 1981).

Dicerandra thinicola (Lamiaceae), recently described as a new taxon (Miller, 1993), is a small shrub that occurs in one area of oak scrub in Titusville. The other, related woody species of *Dicerandra* are narrowly-distributed (Huck et al., 1989), Florida endemics (Mueller et al., 1989), all listed as endangered by the Fish and Wildlife Service (Marois, 1997).

Pteroglossaspis ecristata (false coco, Orchidaceae, Formerly Category 2) is a large, terrestrial orchid (Luer, 1972) with fairly wide distribution in dry sites (Wunderlin, 1982). It is known from Merritt Island (Poppleton et al., 1977) and the Atlantic Coastal Ridge (Hames, 1995).

Warea carteri (Carter's warea, Brassicaceae, Listed Endangered) is an annual plant of xeric habitat. The occurrence of *Warea carteri* in Brevard County is anomalous. It is a species primarily of the Lake Wales Ridge

TABLE 5. Distribution of rare scrub fauna across scrub landscapes in Brevard County[1].

Species	Cape Canaveral & Barrier Island	Merritt Island	Atlantic Coastal Ridge	Ten Mile Ridge
Aphelocoma coerulescens (Florida Scrub-Jay)	present	present	present	present
Drymarchon corais couperi (Eastern indigo snake)	present	present	present	present
Gopherus polyphemus (Gopher tortoise)	present	present	present	present
Rana capito aesopus (Florida gopher frog)	absent	present	present	unknown
Podomys floridanus (Florida mouse)	absent	present	present	unknown
Pituophis melanoleucus mugitus (Florida pine snake)	present	present	present	unknown
Sceloporus woodi (Florida scrub lizard)	absent	absent	present	unknown
Tantilla relicta neilli (Florida crowned snake)	unknown	unknown	present	unknown
Tantilla relicta pamlica (Coastal dunes crowned snake)	unknown	present	unknown	unknown

[1] Occurrence of species on the Osceola Plain Ridge is unknown.

(Mueller et al., 1989; Christman and Judd, 1990) that was observed once at Spessard Holland Park on the outer barrier island in Brevard County (Hames, 1995) but has not been seen again.

Schwalbea americana (American chaffseed, Scrophulariaceae, Listed Endangered) is a perennial herb of Coastal Plain pinelands (Small, 1933; Radford et al., 1968). It occurred historically in Brevard County (Hilsenbeck, 1995), but there are no recent records.

Scrub is also known for the rare, threatened, and endangered fauna dependent on it. These species show some differences in distribution across scrub landscapes in the county (Table 5).

The Florida Scrub-Jay (Corvidae, Listed Threatened) is endemic to the state and dependent on oak scrub and scrubby flatwoods as habitat (Woolfenden and Fitzpatrick, 1984; 1991; Breininger et al., 1995; 1996a). It occurs on all the ridges in Brevard County that have been studied (Breininger et al., 1994; Swain et al., 1995; Stith et al., 1996) (Table 5). This scrub species can also be common in areas predominantly saw palmetto-lyonia that have patches of scrub oaks (Breininger et al., 1991).

The gopher tortoise (Testudines: Testudinidae; State Special Concern) is a large terrestrial turtle occurring on the Southeastern Coastal Plain from eastern Louisiana to southern South Carolina (Diemer, 1992) in a variety of upland habitats. Its burrows are important to numerous vertebrate and invertebrate species. Gopher tortoises occur widely on scrub ridges in Brevard

County (Swain et al., 1995) (Table 5), but they have been studied most extensively on Merritt Island (Breininger et al., 1988; 1991; 1994b; Smith et al., 1997).

The eastern indigo snake (Squamata: Colubridae; Listed Threatened) is now restricted to Florida and southern Georgia where it uses a variety of habitats but typically winters in gopher tortoise burrows (Moler, 1992). It occurs widely on scrub ridges in Brevard County (Breininger et al., 1994a; Swain et al., 1995) (Table 5).

The Florida mouse (*Podomys floridanus*) (Rodentia: Critcetidae; State Special Concern) is endemic to the state and associated with xeric upland vegetation, particularly scrub and sandhills (Layne, 1992) where it frequently uses gopher tortoise burrows. It is known from Merritt Island (Stout, 1980) and the Atlantic Coastal Ridge (Swain et al., 1995) (Table 5). It has not been found in recent studies in apparently suitable habitat on CCAS (Oddy, 1997).

The Florida gopher frog (Anura: Ranidae; State Special Concern) is known from upland, xeric habitats in Florida associated with gopher tortoise burrows (Godley, 1992) but is absent from most coastal islands and dunes. It is present but relatively uncommon on Merritt Island (Breininger et al., 1994a) and occurs on the Atlantic Coastal Ridge (Swain et al., 1995).

The Florida scrub lizard (*Sceloporus woodi*) (Squamata: Iguanidae) is endemic to Florida with a disjunct range occurring in upland xeric habitat including scrub and sandhills (DeMarco, 1992). It occurs on the Atlantic Coastal Ridge but is apparently absent from Merritt Island (Breininger et al., 1994a) and Cape Canaveral (Table 5).

The Florida pine snake (*Pituophis melanoleucus mugitus*) (Squamata: Colubridae; State Special Concern) is a coastal plain species, ranging from South Carolina to Florida. It occurs in xeric habitat including sandhills and scrub (Franz, 1992). It is known to occur on Merritt Island and Cape Canaveral (Breininger et al., 1994a) and on the Atlantic Coastal Ridge (Swain et al., 1995).

The Florida crowned snake (*Tantilla relicta neilli*) (Squamata: Colubridae) is a fossorial (burrowing) species (Breininger et al., 1994a) reported from one site on the Atlantic Coastal Ridge (Swain et al., 1995), but its status in Brevard County is poorly known.

The coastal dunes crowned snake (*Tantilla relicta pamlica*) (Squamata: Colubridae) is a poorly-known, fossorial species (Breininger et al., 1994a). It has been found on Merritt Island in Volusia County in recent work (Seigel, 1997) (Table 5).

Conservation of scrub within Brevard County—Federal Property—Almost half (44%) of the scrub in Brevard County is contained within Federal government ownership on the ridges of Cape Canaveral and Merritt Island; these include the Kennedy Space Center/Merritt Island National Wildlife Refuge/Canaveral National Seashore complex (15.4%) and Cape Canaveral

Air Station (28.7%) (Table 3). These areas were acquired originally for national defense and space program purposes; however, environmental laws and agency policies increasingly emphasize protecting and enhancing ecological resources within the agency missions (NASA, 1995; Goodman, 1996).

John F. Kennedy Space Center is located on the northern part of Merritt Island and consists of approximately 57,000 ha of land and open water lagoons. NASA acquired the northern part of Merritt Island in 1962 to support the space program and provide a safety and security buffer area (NASA, 1979). Lands not actively used in the space program are managed by the U.S. Fish and Wildlife Service (FWS) as Merritt Island National Wildlife Refuge or by the National Park Service as Canaveral National Seashore.

Cape Canaveral Air Station occupies the Cape Canaveral barrier island and has an area of about 6,394 ha. It was acquired by the U.S. Air Force in the early 1950s and is managed by them.

State and county property—Federal lands containing scrub are all on Merritt Island and Cape Canaveral, leaving scrub of the Atlantic Coastal Ridge and Ten Mile Ridge unprotected. The Brevard County Environmentally Endangered Lands (EEL) Program was established by referendum in September 1990. Recommendations for lands to be acquired under the EEL Program are made by the Environmentally Endangered Lands Selection (EELS) Committee, a volunteer committee composed of seven individuals with recognized expertise in botany, ecology, and conservation biology. The EELS Committee began by developing criteria using species, natural community, and landscape approaches for selecting sites that met the overall objective of protecting biological diversity in Brevard County. These criteria have been used to evaluate sites offered to the EEL Program and to develop proactive acquisition initiatives.

Review of available biological data indicated that scrub communities should have high priority for protection in Brevard due to the concentration of rare species in scrub and degree of habitat loss and fragmentation (Swain et al., 1993). The EELS Committee and county staff developed the Scrub Jay Refugia CARL Proposal (EELP, 1992b) as one of its three major initiatives. The objectives of this proposal were to acquire four core areas of scrub habitat: Titusville Airport vicinity, between Rockledge and Eau Gallie, Valkaria Airport vicinity, and along the Ten Mile Ridge to provide for the survival of scrub habitats and organisms. A fifth core area for scrub was within the existing Sebastian River CARL project (now St. Sebastian River Buffer Preserve) (Snodgrass et al., 1991). The Scrub Jay Refugia Proposal was submitted in January 1992 and added to the CARL list in 1993. As additional information on mainland scrub was developed (Swain et al., 1995), boundaries of this project were modified and incorporated into the Coastal Scrub Ecosystem Initiative CARL proposal (EELP, 1995).

Acquisitions by Brevard County have occurred in seven sites of the

Coastal Scrub Ecosystem project. At Valkaria, 62.6 ha have been acquired in a combination of direct purchases and mitigation donations; other donations and purchases are pending. North of Valkaria, along Jordan Blvd., 143 ha have been acquired and additional purchases are pending. On the Ten Mile Ridge, the Micco Scrub site consisting of 571.8 ha of scrub and flatwoods was acquired. In the Titusville Airport core, one acquisition of 21.0 ha has been completed. In the Rockledge core, 59.9 ha have been acquired. The *Dicerandra* Scrub site in Titusville, consisting of 17.8 ha, has been acquired. The Malabar Scrub Sanctuary, 159.9 ha of scrub, flatwoods, and marshes, has been acquired.

Some coastal scrub was included in the Maritime Hammock Initiative (EELP, 1992a) CARL Project. Acquisitions by the Brevard County EEL Program in this project total 86.2 ha. The major scrub acquisition within this project has been the Coconut Point site, consisting of 21.9 ha. Additional lands have been acquired by the U.S. Fish and Wildlife Service, the State of Florida, and the Mellon Foundation for the Archie Carr National Wildlife Refuge (USDI, 1990; DeFreese and MacPherson, 1998).

With the assistance of the Florida Community Trust (FCT) Program, 13.8 ha of sand pine scrub have been acquired and added to the existing Turkey Creek Sanctuary in the City of Palm Bay (EELP, 1991). Along Crane Creek in Melbourne, 8.9 ha of sand pine scrub and wetlands have been acquired by the EEL Program.

Major acquisitions in the St. Sebastian River Buffer Preserve have been completed by the State of Florida Department of Environmental Protection (DEP) and the St. Johns River Water Management District (SJRWMD); in Brevard County, these total 3,862 ha of wetlands, flatwoods, and some scrub. In northern Brevard County, the SJRWMD, with the assistance of the Brevard County EEL Program, has acquired the Buck Lake tract of 3,100 ha of wetlands, pine flatwoods, and some scrub. South of Buck Lake around South Lake, the SJRWMD and the Florida DEP have acquired 2,061 ha of wetlands, pine flatwoods, and some scrub.

Two other county and state acquisitions contain some scrub. The Enchanted Forest Sanctuary (159.0 ha) is primarily mesic and hydric hammocks; however, a scrub ridge (ca. 20.2 ha) runs through the center of it. The Kabboord Sanctuary (181.7 ha) is primarily hydric hammock and salt marshes, but there is a small strip of scrub on the eastern boundary of the site adjacent to KSC. Scrub occurs on some county parks (Wickham Park, Spessard Holland Park, and the Coconut Point North site) that are not part of the EEL program.

The scrub habitat planning process (SCDP; Swain et al., 1995) developed four alternative reserve designs that recommended establishing and managing a protected area network consisting of two-thirds of the existing scrub of non-Federal lands of Brevard County to maintain the viability of the Florida Scrub-Jay and other endangered and threatened scrub species.

This planning process was eventually rejected by the County Commission and not implemented (Noss et al., 1997).

Scrub management and restoration—In the pre-settlement landscape, scrub systems were maintained by periodic fire, and fire frequency varied among scrub types (Abrahamson and Hartnett, 1990; Myers, 1990). Scrub dominated by sprouting species (oaks, ericads, palmettos) regenerates rapidly after fire with little change in species composition (Abrahamson, 1984a; 1984b; Schmalzer and Hinkle, 1992a). Sand pine (Webber, 1935), Florida rosemary (Johnson, 1982; Johnson and Abrahamson, 1990), large-flowered rosemary, *Dicerandra* spp. (Menges, 1992), and some other species (Menges and Kohfeldt, 1995) regenerate from seed stored in the soil or, in sand pine, in serotinous cones. Scrub fires were often intense (Myers, 1990). Scrub types, especially those without much saw palmetto, do not burn as readily as communities such as sandhill (Webber, 1935; Myers, 1990) or flatwoods (Abrahamson and Hartnett, 1990). Most scrub oaks (*Q. chapmanii, Q. geminata, Q. myrtifolia*) have the potential to become tree size if unburned for sufficient time. Historically, this occurred where natural firebreaks protected a site and lead to the formation of xeric hammocks (Myers, 1990). With fire suppression and landscape fragmentation, much scrub has remained unburned for long periods. This creates serious management problems. Problems include: accumulation of high fuel loads that make prescribed burning difficult and create the potential for severe wildfire, loss of obligate seeding species with limited adult life spans, oaks reaching a size where fire will no longer kill above-ground stems, and loss of habitat suitability for species requiring shrub habitat structure.

Fire management planning for protected areas throughout Florida now generally utilizes prescribed burning (Myers, 1990). For example, fire management planning for scrub at Archbold Biological Station on the Lake Wales Ridge attempts to provide spatial and temporal heterogeneity across the landscape using a mosaic of units of various sizes burned at various fire-return intervals (Main and Menges, 1997). The system is built around five fire-return intervals, each of which is a range of years within which individual burn units are planned to re-burn. A key characteristic is the assignment of modal fire-return intervals to vegetation types (e.g., most scrubby flatwoods will burn every 6–9 years, most Florida rosemary scrub will burn every 20–59 years). Using fire-return intervals, rather than a fixed number of years, increases heterogeneity and creates flexibility, including the ability to absorb most lightning-ignited fires. The goal at Archbold is to promote variation in the timing of fires, fire patchiness, fire intensity, and size of burns. Recent fire management planning has shifted most burns to the natural ignition season (Main and Menges, 1997).

A general policy of fire suppression was in effect on KSC between 1963 and 1975 at which time limited prescribed burning was initiated. After severe wildfires during the 1981 drought, a more extensive prescribed fire program was instituted providing a three year fire cycle for most upland vegetation (Lee et al., 1981; Adrian et al., 1983). As initial fuel reduction goals were achieved, fire prescriptions have been modified to meet natural resource management goals (Adrian and Farinetti, 1995).

During the period of fire suppression, landscape changes occurred including: loss of openings [patches of bare ground] in scrub, increases in pine density in flatwoods, development of pine forests on abandoned agricultural sites and other cleared land, and replacement of swale marshes by hardwood swamps (Duncan et al., 1996; Schmalzer et al., 1996). Prescribed burning since 1981 has reversed some but not all of these trends. In a scrubby flatwoods landscape, burning reduced pine density and increased openings, but pine forests that developed on disturbed areas have remained (Duncan et al., 1996). In an oak scrub landscape, burning did not increase openings, and hardwood swamps that established in swales also persisted (Duncan et al., 1996).

Certain NASA construction projects impact Florida Scrub-Jay habitat. Under an agreement with the USFWS Endangered Species Office, NASA agreed to compensate loss of Scrub-Jay habitat to new construction by restoring habitat on KSC. Past fire suppression, landscape fragmentation, and exclusion of some areas from fire management units resulted in areas of scrub whose habitat value was low and that could not be restored by prescribed burning alone.

For oak or oak-saw palmetto scrub unburned for >25 years, even intense fires may not kill above-ground oak stems. Restoring scrub of this condition often requires cutting and burning. Scrub restoration using cutting and prescribed burning has been underway on KSC since 1992 (Schmalzer et al., 1994). Different mechanical techniques (Brown tree cutter, Kendall tree cutter, V-blade, K-G blade) have been used followed by prescribed burning. Mechanical treatments have been implemented carefully to minimize both soil disturbance and damage to saw palmetto. A monitoring plan is in place to determine if these procedures succeed (Schmalzer et al., 1994). Sprout regeneration has been good on all sites. All mechanical techniques produced more soil disturbance than fire, and soil disturbance often resulted in a temporary increase in herbaceous, weedy species (Schmalzer and Boyle, 1997). Reestablishment of saw palmetto cover has been slower than on sites burned without cutting (Schmalzer and Boyle, 1997).

Mechanical techniques of scrub restoration must be used carefully. Mechanical disturbance to scrub can have long lasting impact that may be permanent without intensive restoration efforts if damage to saw palmetto rhizomes is too extensive or severe. Saw palmetto is the principal species that carries fire in Brevard scrub, and it revegetates areas where it has been removed poorly (Breininger et al., 1988; Breininger and Schmalzer, 1990). Although severely disturbed scrub areas can provide habitat for at least 10–20 years after clearing, a habitat structure often develops in large, disturbed areas that burns poorly; thus, these areas lose their suitability for species of conservation concern (Breininger and Schmalzer, 1990).

There is substantial variability in growth rates of scrub vegetation within and among sites (Schmalzer and Hinkle, 1992a; 1992b; Schmalzer and Boyle, 1997). Scrub that has been long-unburned may grow more rapidly than scrub burned within modal return-intervals (Schmalzer and Boyle unpublished) and may require more frequent fires during an initial restoration period.

On the federal lands of CCAS, fires were suppressed from its acquisition until the recent initiation of a program of prescribed burning (Johnson Controls World Services, Inc., 1991). Planning for fire management at CCAS has been undertaken, but, to date, only a small portion of the site has been burned. Air Force construction impacts to scrub habitat are being compensated through on-site restoration utilizing cutting and burning of scrub.

The habitat conditions of most of the scrub on the mainland of Brevard County is poor because it has not burned in 20–50 years (Swain et al., 1995; Boyle, 1996). Scrub acquired for conservation management in Brevard County will require intense management. Some techniques for conducting high intensity scrub fires have been developed (e.g., Doren et al., 1987). Combinations of cutting and burning will be required in much of the scrub acquired for conservation on the mainland of Brevard County. To date, only one of the sites acquired by state or county initiatives, the St. Sebastian River Buffer Preserve, has undertaken active fire management. However, the Sanctuary Management Manual for the Brevard County EEL Program (EELP, 1997) recognizes the role of fire management in conservation areas. Some sites may require actions in addition to prescribed burning. For example, sand pine has expanded into areas not previously occupied due to fire suppression. Logging to reduce pine densities may be required in some sand pine scrub.

SUMMARY—Information from a wide variety of sources is synthesized here to ascertain the status of scrub habitats in Brevard County, east central Florida, an ecosystem of significant conservation interest.

The scrub ecosystems in Brevard County are comprised of five geologically distinct ridges: Cape Canaveral and the outer barrier island, Merritt Island, the Atlantic Coastal Ridge, the Ten Mile Ridge, and the Osceola Plain Ridge. This paper quantifies differences among these ridges from an ecological perspective.

A spatial analysis of soil types in each ridge shows a prevalence of young, alkaline, well-drained soils on the outer barrier island including Cape Canaveral. All other ridges have predominantly older, acid soils. Excessively-drained soils are most abundant on the Atlantic Coastal Ridge. Moderately-drained soils are a feature of the lower elevation Merritt Island, the Ten Mile Ridge, and the Osceola Plain Ridge.

Coastal scrub is found on the alkaline soils of the outer barrier island

and Cape Canaveral. Merritt Island and the three mainland ridges support a matrix of oak scrub and scrubby flatwoods with a far greater proportion of scrubby flatwoods on the mainland ridges, especially at lower elevations. Sand pine scrub is found predominantly on the excessively-drained soils of the Atlantic Coastal Ridge.

Twelve scrub-associated plant species on the ridges of Brevard County are of national conservation concern. Five of these species occur only on the coastal scrub of the outer barrier island. One plant, *Dicerandra thinicola,* is found only on the Atlantic Coastal Ridge, and Brevard County is its only known location.

Almost half (44%) of the scrub in Brevard County occurs within federal properties on Kennedy Space Center/Merritt Island National Wildlife Refuge and Cape Canaveral Air Station. Conservation of this scrub is dependent on protection measures and environmental regulations that pertain to federal lands.

Significant county and state initiatives for scrub conservation have focused largely on the Atlantic Coastal Ridge and the Ten Mile Ridge, which together represent approximately half (49.7%) of the remaining scrub in Brevard. These acquisition efforts will protect only a small proportion of these mainland ridges.

Most Brevard County scrub has been fire suppressed for 20–50 years. Larger-scale fire management is currently limited to Kennedy Space Center/ Merritt Island National Wildlife Refuge and the St. Sebastian River Buffer Preserve. Active fire management will be critical at all other federal, state, and locally-acquired protected areas to ensure long-term viability of this ecosystem.

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APPENDIX

Descriptions of Scrub Soil Series in Brevard County (Huckle et al., 1974).

Astatula fine sand is a nearly level to gently sloping, excessively drained, acid, sandy soil on high undulating ridges. It has low organic matter content and low natural fertility. The water table is typically below 120″ (305 cm). This series is better drained than Pomello and lacks the A2 and B horizons of Paola.

Canaveral sand is a nearly level and gently undulating, moderately well drained, alkaline, sandy soil mixed with shell fragments. The map unit consists of 60% Canaveral sand and 30% a more poorly drained Canaveral sand in sloughs between ridges with a thicker, darker surface layer and the water table closer to the surface for longer periods. Canaveral sand is not as well drained as Palm Beach but better drained than Anclote.

Cocoa sand is a nearly level and gently sloping, well drained, neutral, sandy soil over coquina. The water table is >72″ (183 cm) all year.

Orsino fine sand is a nearly level, moderately well drained, acid, sandy soil on moderately low ridges and between high ridges and poorly drained areas. The water table is between 40–60″ (102–152 cm) for >6 months, during dry periods it is >60″ (152 cm), and during wet periods between 20–40″ (51-102 cm) for 7 days to 1 month.

Palm Beach sand is a nearly level and gently sloping, excessively drained, alkaline, sandy soil on dune-like ridges that roughly parallel the Atlantic Ocean and consists of mixed sand and shell fragments. The water table is >120″ (305 cm). This series is better drained than Canaveral sand.

Paola fine sand is a nearly level to strongly sloping, excessively drained, acid, sandy soil of the tops and sides of ridges. This series is better drained than Orsino and much better drained than Immokalee or Myakka.

Pomello sand is a nearly level, moderately well drained, acid, sandy soil on broad low ridges and low knolls in the flatwoods. The water table is between 30–40″ (76–102 cm) for 2–4 months per year and between 40–60″ (102–152 cm) for >6 months per year. This series is better drained than Immokalee or Myakka but more poorly drained than St. Lucie.

St. Lucie fine sand is a deep, nearly level to strongly sloping, excessively drained, acid, sandy soil on high dune-like ridges and isolated knolls. The water table is below 120″ (305 cm).

Tavares fine sand is a nearly level and gently sloping, well drained, acid, sandy soil on narrow to broad, moderately low ridges. The water table is between 40–60″ (102–152 cm) for >6 months per year and >60″ (152 cm) in the dry season. This series is better drained than Immokalee or Myakka but less well drained than Astatula, Paola, or St. Lucie.

Welaka sand is a nearly level, well drained, sandy soil on moderately broad ridges interspersed with long, narrow sloughs. The water table is between 40–60″ (102–152 cm) during the rainy season but is usually below 60″ (152 cm). It is acid near the surface and neutral to alkaline at depth.

REACTION OF CHROMIUM(VI) WASTES WITH SUGARS

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Abstract: *Aqueous etching wastes from the electronic industry contain heavy metal ions such as chromium(VI), chromium(III) and copper(II). In remediation of this waste, chromium(VI) should be reduced to chromium(III), and then removed via precipitation or extraction. This report describes results of chromium(VI) reduction using water-soluble sugars (sucrose and glucose) for remediation of aqueous etching wastes from this industry. In strong acid solutions (pH <1.0), the reaction was first-order with respect to chromium(VI) concentration in the presence of excess sugar. The evidence shows that glucose can be oxidized into carbon dioxide eventually and that sugars (and probably other materials readily available in Florida) are very efficient and economical in chromium(VI) reduction. Sugar concentration, pH, and temperature affected the rate of reduction.*

Risk assessment for chromium contamination must account for the ability of chromium to transform between two environmentally stable oxidation states, Cr(VI) and Cr(III). Chromium(VI), a human carcinogen, is extremely mobile, and thus is toxic to organisms, including human beings. Fortunately, chromium(III) is less toxic because it is present as hydroxo species in neutral solutions, which have low mobility, or function as metal-chelate compounds.

The existing treatment processes for chromium generally involve the aqueous reduction of chromium(VI) to chromium(III) by a reducing agent and subsequent precipitation of the less soluble chromium(III) hydroxide at pH near-neutral ranges. $FeSO_4$ is commonly used for the reduction of aqueous chromium(VI) species; Fe(III) and Cr(III) are then co-precipitated at pH 5–6. Zero-valent metals, such as iron, are also used for the chromium(VI) reduction. Many organic compounds reduce chromium(VI) to chromium(III), and then reduce the toxicity of chromium released to the environment. In particular, such hydroxylated organic compounds as ethanol (Li, 1988), glycerol, and glucose (Wang and Xiao, 1995) are highly reactive with chromium(VI) in aqueous solutions. Phenol and its derivatives were used for the chromium(VI) reduction in acidic media (Elovitz and Fish, 1994, 1995). The reaction was first-order with respect to concentration of both $HCrO_4^-$ and the phenol reductant; the rate increased with decreasing solution pH. The rate constant was a function of the hydrogen concentration. In this reaction, a chromate-phenol ester intermediate is formed first, and then electron-transfer occurs. Phenols with electron-donating ring substituents are clearly more reactive than unsubstituted phenols or phenols with electron-withdrawing substituents. Hydroxylamine (Scott, et al., 1974) was reported to be reactive with chromium(VI) species. In the pH range of 0.0–4.7, the reaction proceeds by two equivalent steps following formation of an *O*-bonded chromate ester. The ester undergoes internal oxidation and reduction involving acid catalysis.

Enzymatic reduction of chromium(VI) species was reported by Wang and Shen (1995). A membrane-associated, constitutive enzyme was found to mediate the transfer of electrons from NADH to chromate ion. Many cultures of microorganisms reduce chromium(VI). For example, chromium(VI) was the final electron acceptor in the respiratory chains of *Pseudomonas aeruginosa, Bacillus subtilis, P. fluoresens, and Enterobacter cloacae* in the absence of oxygen and nitrate. Chromium(VI) was also quantitatively transformed to chromium(III) largely by soluble reductase activity in *E. coli* ATCC 33456 (Wang and Shen, 1995). Among limited natural aliphatic compounds utilized by the chromium(VI)-reducing bacteria under aerobic conditions, low molecular weight sugars (e.g., glucose), amino acids, glycerol, glycine, and fatty acids served as electron donors for chromium(VI) bacteria reduction by several organisms, such as *Pseudomonas fluorescens* LB 300, and *Bacillus sp.*

Wang and Shen (1995) reported chromium(VI) reduction over a chromium(VI) concentration range of about 20–100 parts per million (ppm) at pH 5–9. The reaction was sensitive to the pH of solutions. The rate of chromium(VI) reduction peaked at pH of 7 and decreased with pH higher than 7. The reaction almost ceased at pH < 6. The glucose concentration limited the rate of chromium(VI) reduction, which virtually ceased after glucose was completely utilized in spite of the initial chromium(VI) level. Chromium(VI) reduction continued throughout the incubation when additional glucose was added. Because of chromium(VI) toxicity toward biological activity, the rate of chromium(VI) reduction decreased with time and eventually ceased at the initial chromium(VI) concentration.

In this report, common sugars, sucrose and glucose, are used for the reduction of chromate which is an aqueous waste from chemical etchants used in electronic firms in Florida and elsewhere. It was presumed that the waste would be a barrel of an aqueous mixture of copper(II), chromium(III) and chromium(VI) at a low pH (<1) (Ghandi, 1994). Extraction of copper(II) ion by a cloud-point technique has been studied previously (Wang et al., 1996), and so has the extraction of chromium(III)by cloud-point extraction (Wang et al., 1999). The critical step is the efficient, inexpensive reduction of chromium(III) Sugars, available from a variety of sources in Florida, seem to be reducing agents that satisfy our requirements.

MATERIALS AND METHODS—*Chemicals*—Potassium chromate, ACS reagent grade was purchased from Fisher Scientific Company (Fair Lawn, New Jersey). Glucose and sucrose (cane sugar) were purchased from Sigma Chemical Company and a food supermarket, respectively. Diphenylcarbazide was obtained from Aldrich Chemical Company. All other chemicals used in these experiments were analytical reagents.

Chromium(VI) measurements—Chromium-containing samples were digested in 1:1 HNO_3/H_2SO_4 solution until acid fumes were observed, and then diluted with pH 1.0 aqueous solution. For total chromium measurement, the sample was completely oxidized to chromium(VI) by treatment with $KMnO_4$ until the purple color persisted at 90°C. After that, a 5 % aqueous NaN_3 solution was added to reduce excess $KMnO_4$ at pH 1.0. A 5-mL aqueous sample was mixed with 2 mL of diphenylcarbazide/ acetone solution (0.2% w/v) to make a violet- colored compound with unknown composition in acid solutions at pH = 1.0 ± 0.3. Absorbance at 530 nm was measured with a Hewlett-Packard 8152A diode array spectrometer. The concentration range of the measurement was 0.04 ppm to 0.85 ppm with the absorbance of 0.06–0.50, $[Cr(VI)](ppm) = -0.0582 + 2.0059 \times Abs.$, $r^2 = 0.9942$ (cf. Eaton, *et al.*, 1995).

Kinetics of chromium(VI) reduction by sucrose—An initial chromium(VI) concentration of 104 ppm was used for all reduction reactions. The pH of the solution was fixed at either 0.6 or 1.0. Sucrose- to- chromium(VI) molar ratios were 2, 5, and 10. The reactions occurred at 50°C (pH 0.6) and room temperature (pH 1.0). Unreacted chromium(VI) was measured by colorimetric method in acidic solutions. At specific times, a known volume of solution was mixed with 0.2% diphenylcarbazide/acetone solution for unreacted chromium(VI) measurement at 540 nm (see above). The relationship between ln [Cr(VI)] and reaction time was examined.

Sugar stoichiometry—Chromium(VI) with concentrations ranging from 100 to 1000 ppm was treated with either glucose or sucrose in acidic solutions. The completion of reduction was investigated as a function of pH, amount of sugar used, and reaction temperature. Solutions of potassium chromate and sugar with molar ratios of sugar/chromium(VI) ranging from 0.12 to 0.50, were prepared, and the pH was adjusted to 0.4–1.0 with a dilute sulfuric acid or an aqueous sodium hydroxide solution. The mixture was sealed in a test tube and placed in a constant-temperature water bath with temperature adjusted from 23°C to 90°C. After a fixed time, the reaction was terminated by adding an aqueous sodium hydroxide solution until pH of 6–8 was reached. Chromium(III) hydroxide was formed from the neutral solution at elevated temperature and was filtered. The filtrate was diluted to a certain volume with pH of 10 for the measurement of chromium(VI) concentration by the spectrophotometric method.

RESULTS AND DISCUSSION—*Kinetics of chromium(VI) reduction*—A water-soluble sugar is an efficient reducing agent for chromium(VI) reduction in aqueous solution because sugar contains many hydroxyl groups. Sucrose and glucose, used in this research, are common sugars and could be found easily wherever chromium(VI) reduction would be needed, such as on-site waste treatment. Though reagent-grade materials are used in the present study, lower-grade materials would be available as by-products of the sugar industry. The water-soluble sugar generates no toxic wastes when it is oxidized by chromium(VI) species, and the final product is carbon dioxide when it is completely oxidized. The effects of reaction parameters on the reaction rate were investigated.

The reduction of chromium(VI) in acidic solution (pH of 0.6 and 1.0) was investigated by using sucrose with the sucrose/chromium(VI) molar ratios of 2, 5, and 10. Reaction temperatures were fixed at 23°C and 50°C. The chromium(VI) concentration was monitored during the reaction time. The reaction was first-order with respect to [Cr(VI] because ln[Cr(VI)] was a linear function of reaction time (Fig. 1), and observed pseudo-first-order rate constants are listed in Table 1.

The dependence of reaction rate on chromium(VI) concentration and

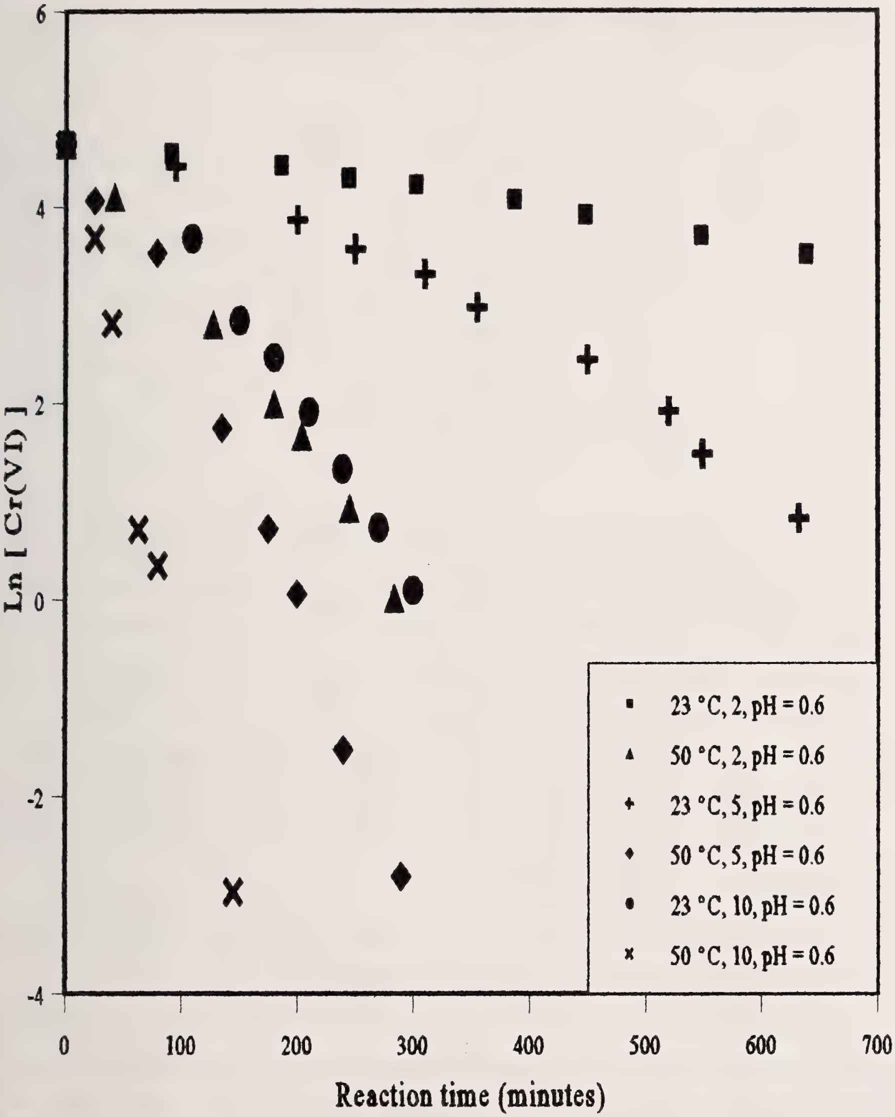

FIG. 1. Relation between ln[Cr(VI)] and the reaction time in chromium(VI) reduction by sucrose. 23°C, 2*, pH = 0.6, ln[Cr(VI)] = 4.985 − 0.00274 t, r^2 = 0.9550, n = 10; 23°C, 5*, pH = 0.6, ln[Cr(VI)] = 5.013 − 0.00613 t, r^2 = 0.9722, n = 10; 23°C, 10*, pH = 0.6, ln[Cr(VI)] = 5.151 − 0.0164 t, r^2 = 0.9709, n = 9; 50°C, 2*, pH = 0.6, ln[Cr(VI)] = 4.908 − 0.0172 t, r^2 = 0.9878, n = 9; 50°C, 5*, pH = 0.6, ln[Cr(VI)] = 5.019 − 0.0260 t, r^2 = 0.9823, n = 8; 50°C, 10*, pH = 0.6, ln[Cr(VI)] = 4.734 − 0.0544 t, r^2 = 0.9859, n = 6; *[sucrose]/[Cr(VI)]

TABLE 1. Kinetics of chromium(VI) reduction by sucrose in acidic solutions.

pH	T (°C)	[Sucrose]/[Cr(VI)] molar ratio	k_{obs} (min^{-1})	t ½ (min)	r^2	N**
0.6	23	2	0.00274	252.9	0.9550	10
0.6	23	5	0.00613	113.1	0.9722	10
0.6	23	10	0.0164	42.3	0.9709	9
0.6	50	2	0.0172	40.3	0.9878	9
0.6	50	5	0.0260	26.7	0.9823	8
0.6	50	10	0.0544	12.7	0.9859	6
1.0	50	2	0.00743	93.3	0.9872	10
1.0	50	10	0.00971	71.4	0.9578	10
1.0	23	10	4.00×10^{-4}	1733	0.9266	10

* Initial chromium (VI) concentration was 104 ppm (2×10^{-3} *M*).
** Number of observations.

temperature, and sugar concentration was investigated. The reaction rate was first order with respect to chromium(VI) concentration. The rate constant increased six-fold when the temperature was increased from 23°C to 50°C (Table 1, sucrose/chromium(VI) molar ratio of 2, pH = 0.6). When the molar ratio was increased from 2 to 5, this significance was decreased and the specific rate constant was quadrupled at a pH of 0.6. At a molar ratio of 10 and pH of 0.6, the specific rate constant was further increased 3-fold compared to one at a molar ratio of 2. At a pH of 1.0, the temperature effect was more significant than that at a pH of 0.6. At a molar ratio of 10 and pH of 1.0, the reaction rate at 50 °C was about 25 times the rate at room temperature (k_{obs}: 9.71×10^{-3} min^{-1} *vs* 4.00×10^{-4} min^{-1}), owing to the slow reaction at room temperature.

Sucrose concentration also affected the reaction rate. At pH of 0.6 and 50°C, the half-life time was 12.7 minutes at the molar ratio of 10, but it was much longer (93.3 minutes) at the molar ratio of 2.

In this reaction system, pH was an important factor (Table 1). At a pH of 1.0 and at room temperature, the reaction was very slow and no significant linear relation between chromium(VI) concentration and reaction time was observed (at a molar ratio of 2). At a molar ratio of 10, first-order kinetics were observed, and the half-life time for chromium(VI) reduction was 1733 minutes. At 50°C and at molar ratios of 2 and 10, the half-life time of chromium(VI) reduction was 93 and 71 minutes, respectively. When the acidity was increased, the specific rate constant increased. At a pH of 0.6 (and at a molar ratio of 2), first-order kinetics were observed and the chromium(VI) half-time at the room temperature was 253 minutes.

The kinetic characteristics of chromium(VI) reduction by sucrose resembled in certain ways chromium(VI) reduction by alcohols and aldehydes in an acidic solution (McAuley and Olatunji, 1977). The chromium(VI) reduction reaction by hydroxylated compounds (alcohol, phenols, and aldehyde) was first order with respect to chromium(VI) concentration, second order with respect to $[H^+]$, and formation of alkoxide, R-O-CrO_3H, (Eqn. 1) (Elovitz and Fish, 1995).

$$R - O - H + HCrO_4^- + H^+ = R - O - CrO_3H + H_2O \tag{1}$$

The Cr(VI) reduction in the acidic solution by sucrose can be explained in a similar way. In solutions with pH <1, sucrose was hydrolyzed into glucose and fructose, and there was an equilibrium between glucose and fructose. It is therefore hypothesized that the mechanism of sucrose oxidation was analogous to the simple alcohols and aldehyde reductants: a preoxidation, equilibrium formation of a chromium(VI) alkoxide, followed by a rate-limiting electron transfer with alkoxide decomposition (Eqn. 2 and Eqn. 3). One sucrose combined with a chromium(VI) ion. Reaction half-lives reported for alkoxide formation of chromium(VI)-alcohol were about 10^{-2}–10^{-1} s (McAuley and Olatunji, 1977). In sucrose-chromium(VI) acidic solutions with excess sucrose, the reduction reactions at 50°C were completed in 145–550 minutes. However, at room temperature, the time required for the complete chromium(VI) reduction was more than 330 minutes. It is reasonable to assume that formation of the chromium(VI) alkoxide was always fast compared with its decomposition through the electron transfer.

$$HCrO_4^- + 1/m\ R(OH)_n \underset{k_r}{\overset{k_f}{=}} [HCrO_4 \cdot 1/m\ R(OH)_n^-]K_e = k_f/k_r \tag{2}$$

$$[HCrO4 \cdot 1/mR(OH)_n^-] \xrightarrow{k_d} \text{products.} \tag{3}$$

The redox step was rate limiting and the rate equation was written as

$$\text{rate} = k_d[\text{ester}] = K_e k_d [HCrO_4^-][R(OH)_n]^{1/m}. \tag{4}$$

In the reaction with excess sucrose, sucrose concentration was assumed constant and k_{obs} was $K_e k_d$, therefore,

$$\text{rate} = k_{obs}[HCrO_4^-]. \tag{5}$$

With excess sucrose at a fixed pH (pH < 1), the reduction exhibited pseudo-first- order kinetics with respect to the chromium(VI) concentration (Eqn. 5).

The chromium(VI) alkoxide equilibrium was independent of pH, and the redox steps must account for the pH dependence of the overall reaction. Elovitz and Fish (1995) reported the overall rate dependence on pH value in redox interaction of Cr(VI) and substituted phenols. At pH < 2, a two-proton pathway dominated, and at pH of 2–5, a single-proton pathway dominated. At pH ≥ 5, a proton-independent pathway was observed. Reasoning by analogy, we presume that in the present study a chromium(VI) alkoxide intermediate was decomposed by an inner-sphere electron to form an intermediate species—chromium(VI)-sucrose alkoxide or chromate-glucose alkoxide. One hydroxy group presumably formed an ester-bond and a glucose molecule combined with more than one chromate ions.

TABLE 2. Reduction of chromium(VI) by glucose with different molar ratios at pH 0.6 and 70 °C.*

$[Cr(VI)]_{feed}$ 10^2 *M*	[Sugar], 10^3 *M*	Molar ratio*	Time, hours	$[Cr(VI)]_{final}$ (ppm)	Reduction (%)
		Glucose			
1.68 (871 ppm)	2.10	0.125	28	225	74.1
1.75 (912 ppm)	2.63	0.15	21	55.4	93.9
1.75	4.38	0.25	4	2.1	99.8
		Sucrose			
1.75	1.4	0.08	23	29.7	96.7
1.75	2.1	0.12	3.5	19.7	97.8
1.75	2.8	0.16	3.5	3.7	99.5
1.75	4.2	0.24	3.5	0.8	99.9
1.75	7.0	0.40	5/6	0.1	100

* [sugar]/[chromium (VI)].

Sugar stoichiometry—If sugars were completely oxidized to CO_2, one mole glucose could reduce 8 moles of chromium(VI) and one mole of sucrose could reduce 16 moles of chromium(VI), (Eqn. 6–8).

$$C_{12}H_{22}O_{11} - 48e^- \Rightarrow 12CO_2 \times 1 \qquad (6)$$

$$C_6H_{12}O_6 - 24e^- \Rightarrow 6CO_2 \times 2 \qquad (7)$$

$$Cr(VI) + 3e^- \Rightarrow Cr(III) \times 16 \qquad (8)$$

The minimum glucose/Cr(VI) molar ratio in the reaction was 0.125 or 1/8, while the minimum sucrose/Cr(VI) molar ratio was 0.063 or 1/16. In a reaction with pH of 0.6 at 70°C, 74% of the chromium(VI) was reduced after 28 hours with glucose/Cr(VI) molar ratio of 0.125, the minimum molar ratio. It showed that all hydroxyl groups were involved in this reduction. Glucose was completely oxidized to carbon dioxide when time is allowed (thermodynamically). Glucose was very efficient for reducing chromium(VI) species to chromium(III) ion in acidic solutions, so that it was economical in a laboratory setting. When the glucose/Cr(VI) molar ratio was increased to 0.15 (20% excess), 94% of 912 ppm chromium(VI) was reduced after 21 hours. When 100% excess of glucose was used, 99.8% of chromium(VI) was reduced in four hours (Table 2). For the sucrose-chromium(VI) reaction, similar results were obtained (Table 2). With a molar ratio of 0.08 (27% excess of sucrose), 97.8% of 912 ppm chromium(VI) was reduced in 23 hours. With 100% excess of sucrose, the reaction rate was increased and 97.8% of chromium(VI) was reduced in only 3.5 hours. Further increasing sucrose concentration should quantitatively reduce chromium(VI) ion to chromium(III) ion. With a sucrose/Cr(VI) molar ratio of 0.40, nearly 100% of chromium(VI) was reduced in less than one hour at 70°C. Excess sugar

TABLE 3. Reduction of chromium(VI) by sucrose in acidic solutions (pH 0.6) at different temperatures.*

$[Cr(VI)]_{feed}$ 10^3 M	[Sucrose], 10^2 M	Temp., °C	Time, min	$[Cr(VI)]_{final}$ (ppm)	(%)
2.77 (144 ppm)	1.47	25	1440	1.80	98.7
2.77	1.47	50	210	2.25	98.4
2.77	1.47	70	80	1.24	99.1
2.77	1.47	90	45	1.10	99.2

* Molar ratio, [sucrose]/[chromium (VI)] was 5.3.

was necessary to convert the carcinogenic chromium(VI) species completely into the non-carcinogenic chromium(III) ion in less than 24 hours.

Reactions with excess sucrose [sucrose/Cr(VI) molar ratio of 5.3] at 25, 50, 70 and 90°C were compared (Table 3). At room temperature, it took 24 hours to reduce 98.7% of 144 ppm chromium(VI). At 50°C, the time required for complete reduction was significantly shortened to 210 minutes (3.5 hours). At 70°C and 90°C, 99% chromium(VI) reduction was achieved in 80 minutes and 45 minutes, respectively. However, reactions at those high temperatures cost energy and might not be considered economical for waste treatment. Temperatures between room temperature and 40°C were considered reasonable in the waste treatment for Florida, indoors or outside; solar-power heating would be reasonable in the Sunshine State.

In order to increase the reaction rate, the adjustment of pH or sugar concentration was more acceptable than the temperature adjustment. The reduction reaction at a pH of 0.4 was fast, and 99.7% of 230 ppm chromium(VI) was reduced in 100 minutes (1.67 hr.,Table 4). At pH of 1.0, however, only 85.8% of chromium(VI) was reduced even in 24 hours. Small pH change affected the reduction reaction rate significantly. For the etching waste from electronic industries, the solution was acidic (< 1.0) (Ghandhi, 1994). Chromium(VI) reduction at this pH or less could be achieved by adding excess sucrose or other water soluble sugar by-products into the solution. Sugars are much better than phenols for chromium(VI) reduction

TABLE 4. Reduction of chromium(VI) by sucrose in solutions of differing pH and temperature.

$[Cr(VI)]_0$ 10^3 M	[Sucrose] 10^3 M	Molar ratio*	pH	Time, hr	T, °C	$[Cr(VI)]_{final}$ (ppm)	(%)
2.21 (115 ppm)	2.34	1.06	1.0	24	70	16.4	85.8
2.21	2.34	1.06	0.6	8	70	1.47	98.7
2.21	2.34	1.06	0.6	120	25	1.29	98.9
4.42 (230 ppm)	2.34	0.53	0.4	1.67	70	0.60	99.7

* Molar ratio was [sucrose]/[Cr(VI)].

because of the efficiency and the products. Phenols are oxidized to quinones, which are also a pollutant. Sugar does not have this problem, though unreacted sugars could be a useful energy source for cyanobacteria and undesirable algae.

CONCLUSIONS—Sucrose and glucose efficiently reduce chromate in chemical echant wastes. They act like phenols and alcohols in acidic solutions. The reduction is first-order with respect to chromium(VI) concentration. The reduction rate is increased with increasing sugar concentration and temperature. The solution pH is critical to the reduction rate; the rate we used was typical of what might be expected for wastes. A higher pH would lead to a slower process. Because sugar contains many hydroxyl groups, the efficiency of reduction using these sugars is much higher than phenols and alcohols. One mole of glucose can reduce up to eight moles of chromium(VI) to chromium(III). For the sake of time, 25–50% excess of sugar was used in acidic solutions. Water-soluble sugar can be hydrolyzed in the strong acidic solutions, and acts like a monosaccharide, such as glucose. Low-grade materials, such as by-products of the sugar industry, or wastewater from sugar industry, probably can be used as well.

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THE HAMMOCK ECOSYSTEM OF HERNANDO COUNTY, FLORIDA.

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ABSTRACT: *The hammock region of Hernando County is part of a larger hammock belt, termed "Big Hammock" by Harper (1911, 1921), which occupies parts of Citrus, Hernando, and Pasco Counties in central Florida. The Hernando Hammock sub-region contains the most significant natural features of Big Hammock, in particular, its two principal geographic entities—the Annuteliga Hammock and the Chocochatti Hammock. Hernando Hammock is extremely diverse in terms of its topography, soils, plant communities, and animal populations; therefore, it is characterized by unusually high quality wildlife habitat and exceptional species richness. Large parts of the Hammock have been altered as a result of agriculture, industry, transportation, and, more recently, by suburban development. Efforts are being made to preserve at least a small part of the area in its current condition.*

THE Hernando Hammock region is among Florida's most significant and earliest known national geographic features, knowledge of which dates back to the 1760s when a band of Creek (proto-Seminole) Indians from Alabama established a long-lived colony near Brooksville (Romans, 1775, 1776). Hernando Hammock includes one of the largest contiguous bodies of high hammock land in Florida and features a diverse array of natural and cultural resources. In most respects, the region is quite similar to the Gainesville and Tallahassee Red Hills regions of northern Florida, regions notable for their picturesque hilly landscapes, abundance of exploitable mineral resources, fertile loamy-textured soils, extensive tracts of upland hardwood forest, and a rich archaeological/historical heritage. Indeed, an early geographic study (Harper, 1911) initially grouped Hernando Hammock with these two regions to comprise collectively the historic Middle Florida Hammock Belt geographic division of peninsular and northern Florida.

The present-day Hammock region in Hernando County has undergone considerable environmental change from its pre-development (pre-1840s) state. It has been so fragmented over the past 150 years as a result of agricultural, silvicultural, industrial, and urban land uses and practices that its geographical identity is partially obscured. Consequently, its central role in the area's early history and economic development has been all but forgotten. Recently, however, the resource value of Hernando Hammock has been re-discovered, and major efforts are being made to preserve a portion of this system. A total of 28,000 acres have or will be purchased through the Save Our Rivers land acquisition program administered by the Southwest Florida Water Management District (SWFWMD) and the Conservation and Recreational Lands program administered by the Florida Department of Environmental Protection (SWFWMD, 1996; Silvey, 1998).

Over 75 years have passed since Dr. Roland Harper published the first modern geographical-ecological description of the region (Harper, 1921, 3: 111–118). The present study is a second modern attempt to document Hernando Hammock's characteristics. This paper represents the first part of that study and serves to supplement and update Harper's work. Specifically, it examines the region's modern ecological conditions and the ecological modifications of the past century-and-a-half. A second paper will provide a description of the pre-settlement vegetational communities in the area, and a third paper will provide an archeological and historical perspective of the region.

PHYSICAL SETTING—*Geography*—The Hernando Hammock region covers a roughly 200 square mile section of west-central peninsular Florida (Figure 1). On various maps (Boyd, 1951; Harper, 1921; Mahon, 1967) Hernando Hammock appears as a long "S" shaped regional feature, about 40 miles long (north–south), between four and eight miles wide, and ranging between 10 miles to over 30 miles inland from the Gulf of Mexico. It stretches southeastward across extreme south-central Citrus County, central Hernando County, and east-central Pasco County. It is a limestone region of high hills, rolling uplands, karst-formed valleys, prairie basins and lakes, fertile loamy soils, and rich upland hardwood forests. Because It contains several features which are also characteristic of the historic Tuscowilla and San Felasco Hammocks and the Tallahassee Red Hills (the former Middle Florida Hammock Belt), it was considered initially as a southerly outlier of the Middle Florida Hammock Belt geographical region (Harper, 1911). Hernando Hammock was later defined as a separate geographical feature—the Hernando Hammock Belt (Harper, 1921)—due to its distinctive vast body of upland hardwood forest, recognized as representing the southern limits of the Southern Mixed Hardwood Forest Region of Alabama, Georgia, and northern Florida (Davis, 1967; Monk, 1965).

As its name implies, the Hernando Hammock region encompasses several thousand acres of upland hardwood, or hammock, forest. The northern half of Hernando Hammock is comprised of two extensive hammock bodies—Annuteliga Hammock and Chocochatti Hammock. Annuteliga Hammock, historically among the largest contiguous bodies of hammock land in Florida, covers a roughly 32 square mile area northwest of Brooksville. It is generally egg-shaped in outline and measures nearly nine miles long and between four and seven miles wide. It is more-or-less rimmed by a series

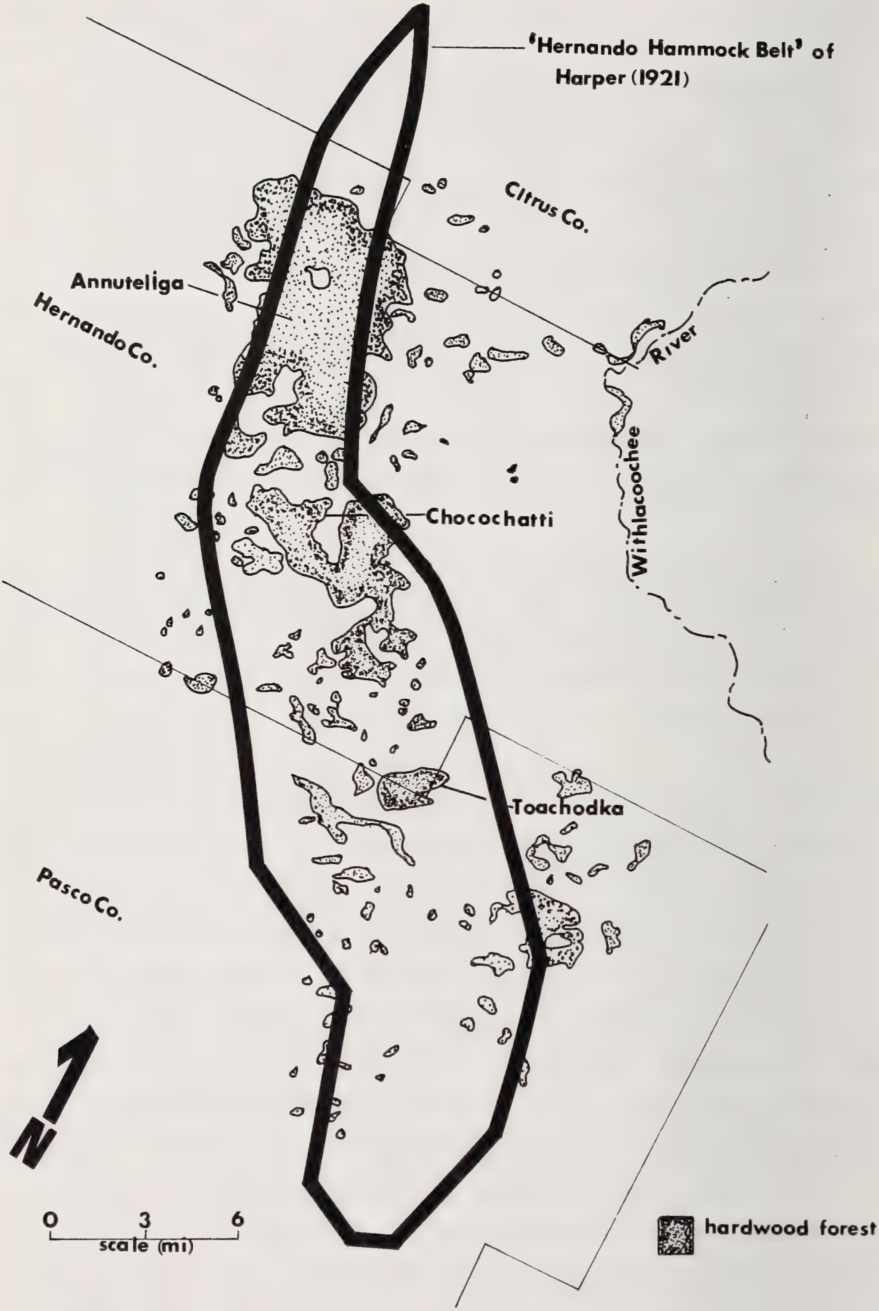

FIG. 1 Location of the Hernando Hammock region in west central Florida.

of high hills which enclose a elongated central valley, arms of which extend outward between some of the hills.

Chocochatti Hammock, located southeast of Brooksville, is an irregularly shaped body of hammock land (which includes sizable scrub and xeric pine forested parcels), covering roughly a 22 square mile area, and measuring nearly eight miles long by three to six miles wide. The terrain is one of lake dotted valleys interspersed among high hills and rolling uplands.

Southeast of Chocochatti Hammock, the hammock bodies are generally small in size, more scattered, and confined to valley and lower hillside situations. The small Toachudka Hammock, the only other named hammock body in Hernando Hammock, straddles the Hernando/Pasco County line five miles southeast of Spring Lake.

The Hernando Hammock region, in addition to its extensive hammock forests, has historically featured sizable tracts of pine-dominated forest of at least three varieties—(1) longleaf pine-xeric oak forest or sandhill, (2) a variant of the northern Florida open longleaf pine flatwoods, and (3) sand pine scrub. Mixed pine-hardwood mesic forests, although only a minor vegetative feature in pre-development times, now cover some areas of Hernando Hammock, particularly in and around Annuteliga and Chocochatti Hammocks.

Several hydrologically unique lake/prairie basins, smaller than but otherwise identical to Payne's Prairie, are found in Annuteliga and Chocochatti Hammocks. The largest, Chocochatti Prairie (today known also as Griffin's Prairie), over 550 acres in extent, has been ditched and drained, as had Lake Bystre before being filled by mining sludge. In Annuteliga Hammock several such basins are present, among the larger being Stafford Prairie Lake and Simmons Prairie Lake.

Several particularly deep, almost vertical-walled sinks, are known to occur in Annuteliga Hammock. The most noteworthy of these sinks was the Devil's Punch Bowl, located about two miles west-northwest of Brooksville. The Devils Punch Bowl was originally an estimated 60 feet deep and 200 feet across (MacKay, 1846c). It was later estimated to be 100 feet across and 50 feet deep (Harper, 1921). In the 1930s, it was described as "a dry sink an acre in extent and from 60 to 80 feet deep. The conformation is that of a mammoth punch bowl, with steep, almost unscalable sides" (Federal Writers Project, 1939:390). In the past, Devils' Punch Bowl, closely related geologically to Devils Millhopper, had generated sufficient public interest to be listed among the State's attractions in early automobile tour books and gazetteers (e.g., Federal Writers' Project, 1939). It was the site of mining operations several years ago.

Other natural features characteristic of Hernando Hammock include hillside (seepage) branch bay forests, muck basin bay swamps, fertile loamy and clayey (and locally stony) upland soils, widespread chert outcrops, and thousands of acres of commercially mineable limerock land.

Geology—The Hernando Hammock region was once characterized as "calcareous and phosphatic hammock lands" (Florida Agricultural Experimental Station, 1938), a label clearly acknowledging the prime role played by the region's geologic history in the genesis and perpetuation of this unique natural feature. The Big Hammock region is underlain by Pliocene, Pleistocene and Recent age sands and Miocene age Hawthorn Formation clayey sands and clays. These surficial deposits are, in turn, underlain by an over thousand-foot thick sequence of limestones and dolomites. These comprise in order of increasing age, the Oligocene age Suwannee Limestone, and the Eocene age Crystal River Formation and Avon Park Formation (Yon and Hendry, 1972; Fretwell, 1985).

Hernando Hammock owes its existence primarily to the Suwannee Limestone, and, in particular its crystalline limestone unit. Suwannee Limestone is a very pale orange, marine bioclastic limestone, partially recrystallized to crystalline, which was deposited in a shallow marine environment and subsequently uplifted to near-surface position by tectonic arching accompanying the post-Oligocene Ocala Uplift (Yon and Hendry, 1972). The Suwannee Limestone and the older deposits generally dip to the southwest and southeast away from the arch crest. In geologic cross section the crystalline limestone unit seems to be closely related to the subsurface high that trends northwest-southeast through Hernando and Pasco counties, and both, in turn, are roughly co-extensive with the geographic extent of the Hernando Hammock region. The crystalline unit at its thickest varies between about 110 to 200 feet thick in Annuteliga Hammock, gradually thinning southeastward and pinching out near the southern tip of Hernando Hammock. Post-depositional karst processes operating atop the Suwannee beds have produced a very irregular surface, the subsurface highs and lows of which closely conform with surface topographic highs (hills) and lows (valleys). The relatively high topographic elevations of Hernando Hammock can be attributed to the Suwannee crystalline unit's greater resistance to surficial dissolution (karst) processes compared to the surrounding, more soluble partially recrystallized limestones (White, 1970). The Hernando Hammock region (and the Brooksville Ridge of which it is a part) is, then, an erosionally resistant feature flanked on the west and east and by topographically lower, mature karstic plains.

During the Miocene age, a very irregular veneer of deeply weathered Hawthorn Formation-Statenville type sands, silty sands, and clays with phosphatic inclusions was deposited over much of the underlying Suwannee Limestone throughout Hernando Hammock. Localized areas of Hawthorn Formation-Devils Millhopper Type clayey sands, clays and sandy limestones, as well as some areas of Suwannee Limestone, cap several of the higher hills and ridges in Annuteliga Hammock (Brooks, 1982).

The geologically-derived calcareous and phosphatic nature of the lands of Hernando Hammock, and, in turn, its derivative rich loamy soils and diverse hardwood forest communities, have combined to impart a distinctly un-Floridian appearance to the region. Indeed, several early observers favorably compared the region to certain valued districts in Alabama, Georgia, North Carolina, even Iowa and Illinois (Eagen, 1874; Barbour, 1882; Harper, 1921; Brooksville Board of Trade, 1910). Geology is the reason why Hernando Hammock, and, in particular, Annuteliga and Chocochatti Hammocks have long been regarded as highly valued lands throughout human history, from the ancient Paleo-Indian epoch, through the early historic Seminole period, and continuing into the present-day as attested by the well-developed agricultural and limerock mining interests now centered in Annuteliga Hammock.

Physiography and topography—The Hernando Hammock region occupies much of the southern portion of the Brooksville Ridge in Citrus, Hernando and Pasco counties. The Brooksville Ridge, part of Florida's Central Highlands physiographic province, is a massive ridge along western peninsular Florida, characterized by particularly high elevations, marked local relief, few persistent valleys (Annuteliga Hammock being one exception), and poorly developed surface drainage patterns. Across short distances, elevations may range between 270 feet and 70 feet NGVD (National Geodetic Vertical Datum); and a few hills in the Pasco County portion of Hernando Hammock exceed 300 feet NGVD. An east-west geologic cross section across central Hernando County illustrates how the structurally uplifted section of Suwannee Limestone rises abruptly inland from the coast to form the core of the Brooksville Ridge. Two localized ranges of particularly high hills centered near Brooksville and Dade City have been recognized as distinct physiographic units—the Brooksville Hills, and Dade City Hills, respectively (Brooks, 1981).

Soils—The Hernando Hammock region falls within two generalized soil associations-the Nobleton-Blichton-Flemington association and the Arredondo-Sparr-Kendrick association (Hyde *et al.,* 1977). The Nobleton-Blichton-Flemington association underlies both Annuteliga and Chocochatti Hammocks. It is characterized by nearly level to strongly sloping, poorly drained to somewhat poorly drained, gray to brown, fine sandy loams to sands less than 40 inches thick over loamy and clayey material. The Arredondo-Sparr-Kendrick association underlies the rest of the Hernando Hammock region. Soils of this association are nearly level sloping, well drained deep fine sands and somewhat poorly drained, yellowish-brown to brown, fine sands 20 to over 40 inches thick over loamy material.

Soils of the Blichton loamy fine sand and Flemington fine sandy loam series closely correlate with the historic and present-day occurrence of the upland hardwood forest community. To a lesser extent, Nobleton, Micanopy, Kanapaha, Sparr, and Wauchula soils support these forests but also support some areas of pine and mixed pine-hardwood forest.

In Chocochatti Hammock, the xeric pine-oak scrub areas are underlain by Astatula, Paola and Pomello fine sands, which are excessively drained, paleo-dune soils. The few areas of longleaf pine-xeric oak forest and pine flatwoods occupy chiefly Candler fine sand and Myakka fine sand soils, respectively.

The region's numerous lake/prairie basins are underlain by the very poorly drained Floridana Variant Loamy fine sand, and, to a lesser extent, poorly drained Basinger and Wauchula find sands. Bay swamps generally occupy Samsula muck soils, and branch bay forests, cypress swamps and mixed hardwood swamps are commonly found on wetter Blichton, Flemington, and Myakka soil sites.

Surface water features—There are few well defined drainage features in Hernando Hammock. Surface water drainage is primarily internal with rainfall percolating through the sand and clay to recharge the Floridan Aquifer. Following heavy rainfall, small intermittent streams receive the runoff and flow to sinkholes where the water either percolates rapidly or collects to form "prairie lakes". During dry periods these channels and prairie lakes are unusually dry, but during wet periods, flooding may occur (Fretwell, 1985).

Prairie lakes, also called sink outlet lakes, several of which are found in Hernando Hammock (e.g., Stafford Prairie Lake, Simmons Prairie Lake, Squirrel Prairie Lake, and, formerly, Chocochatti Prairie and Bystre Lake), are unique hydrologic features (Sellards, 1914). Harper (1921) describes these as large, shallow lakes which become prairie basins in dry seasons or whenever their sink outlets are sufficiently unobstructed. Flooding of these basins may occur if rainfall exceeds percolation rates or if the potentiometric surface of the aquifer rises to or above the base of the sink outlets (Fretwell, 1985). The biologically valuable Paynes Prairie State Preserve in Alachua county is an example of a particularly large prairie basin.

The Hernando Hammock region also contains many moderate-to-small permanent lakes which appear to be surface expressions of water tables perched on impermeable (clayey) materials (Fretwell, 1985; Harper, 1921). Lake Hancock, which straddles the boundary between Hernando and Pasco counties, is the largest of these permanent lakes. Other such lakes include Spring Lake, St. Clair Lake, and Nicks Lake, and a few dozen others (SWFWMD, 1987).

MODERN ECOLOGICAL SETTING—The name, Hernando Hammock, would seem to imply that the region is floristically homogeneous. While it is true that among the remaining natural plant communities the hardwood hammock and its variants predominate, Hernando Hammock still possesses considerable diversity in both the plant and vertebrate wildlife which it supports.

Plant communities—The Hernando Hammock area in the 1840s was covered to a large degree by a vast forests, and included mesic hammock,

TABLE 1. Habitat and food resources for vertebrate species in the forested communities of Hernando Hammock.

Habitat and food resources.
Soils
deep soils for burrows
dry and moist leaf litter
Shrubs, Vines, & Herbs
abundant fruiting shrubs and vines
abundant shrubs and herbs for browsing
Trees
tall snags
dead trees and stumps
dense & moderately dense forest cover
abundant nut- and seed-bearing trees
Ecotonal areas
Cover due to topography

pine flatwoods, sandhill, and sand pine scrub. Some aquatic systems were also present, including small ponds, cypress swamps, and marshes which occurred on adjacent lands still relatively undisturbed. These communities persist today; however, the mesic hammock is the signature community of the area. Since the early 1800s, agricultural, transportation, and industrial development have resulted in the presence of several other, man-made communities such as pine plantations, pasture, disturbed land in the Hammock. This report is primarily a description of Hernando Hammock's natural terrestrial vegetational communities and their associated wildlife, although it must be recognized that all of the communities, whether natural or man-made, now comprise the totality of habitat diversity in the area.

The information concerning the plant and animal species currently occurring in the terrestrial communities of Hernando Hammock appears in Tables 1 and 2, respectively; it was compiled from several published sources, including Beckwith (1967), FGFWFC (n.d.; 1984), Monk (n.d.), the Nature Conservancy (1979; 1982), Dooris and co-workers (1996), and from the observations of the investigators over a 13-year period. Taxonomic guides employed included: Godfrey (1988), Godfrey and Wooten (1979 & 1981), Kurz and Godfrey (1962), Lakela and Long (1976), Wunderlin (1982), Wunderlin and co-workers (1985a, 1987), Wunderlin and co-workers (1992).

Mesic hammock is the ecosystem which impressed those naturalists who first formally described the area and which still impresses residents and visitors with its native beauty and its resemblance to vegetation generally associated with more northern parts of our state. The most obvious component of this community is the preponderance of tall hardwoods, many of which are of large diameter. This component, the overstory, is composed of live oak, pignut hickory, eastern hophornbeam, sweetgum, and remnant longleaf pine and loblolly pine, with the first two listed species dominating. The secondary canopy or understory is composed of smaller trees such as

TABLE 2. Vertebrate species known or expected to occur in the Hernando Hammock which are listed as having special status.

Species	FGFWFC*	USFWS**
Rana areolata aesopus	SSC	C2
Alligator mississippiensis	SSC	T
Drymarchon corais couperi	T	T
Gopherus polyphemus	SSC	C2
Stilosoma extenuatum	T	C2
Aramus guarauna	SSC	
Egretta caerulea	SSC	
E. thula	SSC	
E. tricolor	SSC	
Eudocimus albus	SSC	
Grus canadensis	T	
Haliaeetus leucocephalus	T	E
Lanius ludovicianus		C2
Mycteria americana	E	E
Blarina brevicauda	SSC	C2
Felis concolor coryi	E	E
Myotis austroriparius		C2
Podomys floridanus	SSC	C2
Sciurus niger shermani	SSC	C2
Ursus americanus floridanus	T	C2

* FGFWFC = Florida Game & Fresh Water Fish Commission.

** USFWS = United States Fish & Wildlife Service.

E = endangered; T = threatened; SSC = species of special concern; C2 = candidate for federal listing with some evidence of vulnerability, but for which not enough information exists to justify listing.

American holly, flowering dogwood, yaupon, southern bayberry, and seedlings of overstory species.

The shrub layer is variously developed, depending upon the degree of moisture, the influence of fire, and the degree of physical disturbance prevailing in the hammock. The more moist mesic hammocks on heavy clay soils have a shrub layer dominated by saw palmetto, American beautyberry, bumelia, devil's walking stick, stiff cornel dogwood, and tree sparkleberry. Drier representatives of the mesic hammock have less coverage by saw palmetto and are, generally, of a more open aspect.

Herbaceous species, occupying the lower levels of the hammock, include coral bean, needle palm, several ferns and grasses. In addition, the soils are covered by a thick layer of litter in various stage of decomposition.

Throughout the hammock, but more noticeable on the fringes of the hammock, vines climb and ramble over the trees and shrubs. Common vine species include wild grape, catbrier, yellow jessamine, skunk vine, Virginia creeper, and trumpet creeper. The overall aspect of the hammock in full leaf is one of shade, humidity, and quiet.

Apart from being a very attractive community and an excellent habitat for wildlife, the mesic hammock represents a climax community in Florida and is, therefore, of substantial scientific interest.

Considerable acreage formerly occupied by mesic hammock has been converted to rock mines, pasture, some pine plantations, orange groves (now defunct), and urban/suburban development. The remaining areas today are either undisturbed or are characterized by low density development.

The *sandhill* community, a very uncommon community today, occurs adjacent to and interspersed with the mesic hammock. Dominated by longleaf pine and turkey oak, this habitat occupies somewhat drier sites in Hernando Hammock. Other species include blackberry, bluestems, bracken fern, golden aster, gopher apple, hair grass, low bush blueberry, running oak, saw palmetto, wire grass, among others. For that reason, this community has a more open appearance in contrast to the mesic hammock's dense vegetation. This community has undergone considerable conversion since pre-settlement tumescent soils once occupied by sandhill now support pine plantations, pasture, and urban/suburban development.

The *sand pine scrub* community is still relatively common in Hernando Hammock, although large areas have been converted for various human purposes. Occupying deep xeric soils, the community is recognizable by the occurrence of species such as sand pine and several scrub oak species, with gopher apple, jointweed, lupine, milk pea, prickly pear, rattlebox, reindeer moss, rosemary, rush pink, saw palmetto, scrub clover, and tallow wood as associates. As in other parts of the state, this community in Hernando Hammock has undergone some conversion for human purposes. In particular, sand pine plantations and urban/suburban development now occupy large areas of former scrub.

The *pine flatwoods* community, a community of open aspect dominated by longleaf pine and grasses, has also undergone conversion as a result of logging followed by the development of pine plantations, pasture, and urban/suburban development. Today, as a result of human conversion and natural successional trends, very little of this community persists in its native condition.

Plant species richness—The diversity of the area is such that any list can be said to be incomplete; however, the species listed in Appendix 1, particularly the tree species, are those which are most characteristic of Hernando Hammock's terrestrial communities. Of the extant terrestrial communities in Hernando Hammock, total species richness is greatest in the sandhill and sand pine scrub communities and least in the mesic hammock. In terms of tree species richness, the mesic hammock exceeds all other communities.

Wildlife—Hernando Hammock supports a diversity of wildlife (Appendix 2), and the mesic hammock, sandhill, and sand pine-scrub communities supply excellent food sources and habitats Table 1). Chief food sources are pine seeds, acorns, hickory nuts, all of which are extremely abundant. Other sources include the fruits of the blackberry, dogwood, grape, holly, low bush blueberry, tallow wood, and tree sparkleberry, among others. These species provide wildlife with a reliable, high quality food source.

Excellent habitat is available throughout the forested communities. Deep soils are useful for burrows which are constructed in abundance by gopher tortoises and used by a wide variety of other animals. The numerous tall snags provide nesting sites for cavity-dwelling birds and hunting perches for predatory birds such as the red-tailed hawk. Probably as a result of the availability of nest sites, two species of woodpecker (red-bellied and pileated) are quite common in Hernando Hammock. Other birds find nest sites in the branches of dogwood, tree sparkleberry, southern bayberry and other smaller trees and larger shrubs. Ground-nesting birds such as the chuck-will's widow prepare nests on the thick layers of leaf litter in areas protected by shrubby growth. The large remaining tracts of heavily forested land provide cover, forage, and resting areas for white-tailed deer, fox, and bobcat which can go virtually unnoticed in the dense woods. Hernando Hammock also provides significant ecotonal development as large tracts of forested land adjoins similarly sized parcels of open land in many locations. Lastly, due to topographic differences within Hernando Hammock, the opportunity for cover is substantially higher in the area than in much of the state in which pine flatwoods prevails.

Threatened and endangered vertebrate species—Table 2 lists species occurring or expected to occur in the Hammock which have some type of special status relative to their future survival (Wood, 1995). The list is self-explanatory for the most part; however, comment on two of the species is warranted.

Black bear—This species is well known from western Hernando County, even today. Its appearance in the Hernando Hammock in the past is certain; however, it is observed with much less frequency now. It is included on the list primarily because some sightings have been made, suggesting that it very likely occurs in very low abundance in Hernando Hammock now.

Florida panther—The individuals of this species which have been observed were very likely transients rather than residents in the area. Nevertheless, any panther present are utilizing the areas offering good cover and abundant white-tailed deer population..

Long-term ecological change—The Hernando Hammock region has been the focus of various land use activities since prehistoric days. Prior to Anglo-American settlement in the 1840s, the effects of indigenous peoples on the region's natural resources had been minimal in consequence of the low density of the human population and the primitive agricultural technologies employed. However, after the 1840s land use impacts in the region became gradually more intensive and extensive, effecting long-term ecological changes still evident today. The following discussion focuses on geographical and ecological modifications of the region as a result of altered fire regimes, and agricultural and limerock mining.

The most obvious change is in the geographical extent of Hernando Hammock. Over the years since the General land Office Survey (GLOS) mapping of Hernando Hammock in the 1800 s (Jones, 1844; Lee, 1837; MacKay 1846a, b, d; MacKay and Blake, 1839; U. S. Army, 1836; Washington, 1843), the outline of the region's hammock bodies has been gradually altered. Where before Annuteliga, Chocochatti, and the outlier hammocks were shown as separate bodies, by 1915 significant expansion of hammock lands had occurred (Jones and Morrison, 1915). Large tracts of the GLOS-described "1st and 2nd rate pineland" (on today's Arredondo, Kendrick, and Williston soils) which had largely surrounded Annuteliga and Chocochatti had been by 1915 replaced by a mixed pine-hardwood forest with patches of hammock forest. Today, these same sections, where still forested, support live oak hammocks. Apparently, with increasing settlement came fire suppression practices, championed by the forestry agencies earlier in this century, which allowed hardwoods to invade and overtake these former "1st and 2nd rate pinelands" (cf., Harper, 1921).

Limerock mining has altered the configuration of Annuteliga Hammock, obscuring its boundaries where quarries straddle them and using over 6000 acres of the Hammock's interior and adjoining outlier hammocks. The ecological changes associated with this activity can only be surmised, but likely included habitat loss, possible elimination of some rare plant and animal species, and the destruction of such features as the Devil's Punch Bowl.

Agricultural activities have resulted in the temporary elimination of almost 9000 acres in Annuteliga and Chocochatti. The temporary nature of these activities should be underscored, for already large tracts of secondary growth hardwoods have re-established themselves in former farmlands, and the forest is capable of recovery in present agricultural lands as long as the soils and geological substrate are left intact.

In terms of the species composition of the hammock forests of Hernando Hammock, particularly its trees, little change in overall composition seems to have occurred, with a few notable exceptions. Relative to the pre-development forest, pines have increased in importance, owing largely to land clearing activities, abandonment of farmlands, and artificial plantings. Where the GLOS recorded only small numbers of pines throughout the hammocks of Hernando Hammock, Harper (1921) and Jones and Morrison (1915) observed large acreages of mixed loblolly pine-hardwoods. Loblolly pines are an old field species, and presumably established themselves in abandoned croplands, as they seem to have done in the 1840s and earlier. Cabbage palms, not mentioned in the GLOS records, are now a fairly common tree in the hammocks. Harper (1921) observed that it was customary to let the cabbage palm grow in orange groves and other cultivated ground wherever they can establish themselves. Some of these may be remnants of the original forest (although lack of GLOS mention makes this unlikely), but probably most were distributed by birds. Cabbage palms are tolerated by farmers because they indicate good agricultural land, have ornamental value, and do not heavily compete with field crops for water, light, and nutrients.

Aside from these exceptions, the overall forest composition of Hernando Hammock appears little changed since pre-development days. In comparing the GLOS tree list with tree lists prepared by or included in Eagan (1874), Jones and Morrison (1915), Harper (1921), Beckwith (1967), Matoon (1925), Monk (n.d.), and The Nature Conservancy (1979, 1982), more-or-less the same principal tree species are ever present: live oak, laurel oak, water oak, pignut hickory, southern magnolia, red bay, sweetgum, blue beech, eastern hophornbeam, and swamp chestnut oak. Little can be said, however, regarding the undergrowth as very sparse information is available, historically or presently.

One other feature deserves mention, and that is the lake/prairie basins of Hernando Hammock. These basins have been long used to graze livestock, but since the early 1900s there have been attempts, with variable success, to drain and convert these to croplands. Sellards (1914) describes one such (failed) effort at Lake Bystre. Chocochatti Prairie over the years has been channelized, drained, cultivated, and its Lake Irvin artificially created in an old cypress pond. Such practices here and at other lake/prairie basins throughout Hernando Hammock have certainly altered their vegetative component, but to what degree is presently uncertain because of inadequate past field studies.

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APPENDIX 1.

List of plant species commonly encountered in terrestrial communities in the Big Hammock.

TREE SPECIES

Acer negundo, box elder
A. rubrum, red maple
Carpinus caroliniana, American hornbeam
Carya glabra, pignut hickory
Celtis laevigata, sugarberry
Citrus aurantium, sour orange
Cornus florida, flowering dogwood
Diospyros virginiana, persimmon
Ilex opaca, American holly
Juniperus virginiana, eastern red cedar
Liquidambar styraciflua, sweetgum
Magnolia grandiflora, southern magnolia
M. virginiana, sweetbay
Morus rubra, red mulberry
Myrica cerifera, southern bayberry

Ostrya virginiana, eastern hophornbeam
Persea borbonia, redbay
Pinus clausa, sand pine
P. elliottii, slash pine
P. palustris, longleaf pine
P. taeda, loblolly pine
Prunus caroliniana, Carolina laurel cherry
P. serotina, wild cherry
Quercus chapmanii, Chapman's oak
Q. geminata, sand live oak
Q. incana, bluejack oak
Q. laevis, turkey oak
Q. laurifolia, laurel oak
Q. margaretta, sand post oak
Q. michauxi, swamp chestnut oak
Q. myrtifolia, myrtle oak
Q. nigra, water oak
Q. phellos, willow oak
Q. virginiana, live oak
Sabal palmetto, cabbage palm
Tilia americana, American basswood
Ulmus alata, winged elm
U. floridana, American elm
Vaccinium arboreum, tree sparkleberry
Zanthoxylum clava-herculis, Hercules' club

SHRUBBY SPECIES

Aralia spinosa, devil's walking stick
Asimina pygmaea, dwarf pawpaw
Baccharis glomeruliflora, silverling
B. halimifolia, groundsel tree
Bumelia sp., bumelia
Callicarpa americana, American beauty berry
Cornus foemina, stiff cornel
Erythrina herbaceae, coral bean
Gaylussacia dumosa, low bush huckleberry
Ilex vomitoria, yaupon
Lyonia ferruginea, staggerbush
L. ligustrina, maleberry
Prunus angustifolia, chickasaw plum
Quercus pumila, running oak
Rhapidophyllum hystrix, needle palm
Rhus copallina, winged sumac
Sapindus marginatus, Florida soapberry
Serenoa repens, saw palmetto
Viburnum obovatum, small viburnum

HERBACEOUS & VINING SPECIES

Acalypha gracilis, three-seeded mercury
Adiantium capillus-veneris, Venus hair fern
Ageratina jucunda, hammock throughwort
Amsonia ciliate, fringed bluestar
Amorpha herbaceae, cluster spike indigo bush
Andropogon floridanus, Florida bluestem
A. ternarius, splitbeard bluestem
A. virginicus, broomsedge
Arisaema dracontium, green dragon
Aristida beyrichiana, wiregrass
Arnoglossum floridanum, Florida indian plaintain
Asplenium platyneuron, ebony spleenwort
A. pumilum, dwarf spleenwort
Aster dumosus, rice button aster
A. tortifolius, white-topped aster
Axonopus sp., carpetgrass
Balduina angustifolia, yellow buttons
Baptisia lecontei, bushy wild indigo
Berlandiera subcaulis, Florida greeneyes
Bidens laevis, smooth beggar tick
B. bipinnata, beggar tick
Blechnum occidentale, sinkhole fern
Campsis radicans, trumpet creeper
Ceratiola ericoides, rosemary
Clitoria mariana, blue pea
Crotalaria pallida, smooth rattlebox
Cyanchum scoparium, spiny pod
Dicanthelium commutatum, variable witchgrass
Elephantopis elatus, Florida elephant's foot
Galactia elliottii, Elliott's milk pea
Galium floridanum, bedstraw
Gelsemium sempervirens, Carolina yellow jasmine
Gnaphalium obtusifolium, sweet everlasting
Epidendron conopseum, green fly orchid
Hedyotis procumbens, innocence
Hypericum hypericoides, St. Andrew's Cross
Indigofera caroliniana, Carolina indigo
Justicia cooleyi, Cooley's justicia
Liatris gracilis, slender gayfeather
L. tenuifolia, shortleaf gayfeather
Licania michauxii, gopher apple
Lygodium japonicum, Japanese climbing fern
Melothria pendula, creeping cucumber
Mikania scandens, climbing hemp vine
Mitchella repens, partridge berry
Monotropsis reynoldsiae, pygmy pipes
Monarda punctata, horsemint
Nolina brittoniana, Britton's beardgrass
Opuntia humifusa, prickly pear cactus
Paederia foetida, skunk vine
P. rigidulum, redtop panicum
Parthenocissus quinquefolia, Virginia creeper
Passiflora incarnata, maypop
Paspalum setaceum, thin paspalum

Phytolacca americana, pokeberry
Pluchea odorata, camphorweed
Polygonella gracilis, wireweed
Polypodium polypodioides, resurrection fern
Pteridium acquilinum, bracken fern
Pycanthemum floridanum, Florida mountain mint
Salvia lyrata, lyre-leaved sage
Smilax auriculata, wild bamboo
S. bona-nox, catbrier
Solidago chapmanii, Chapman's goldenrod
Sorghastrum secundum, lopsided indiangrass
Tillandsia setacea, wild pine
T. usneoides, Spanish moss
Toxicodendron radicans, poison ivy
Trichostema dichotomum, blue curls
Vaccinium myrsinites, shiny blueberry
Viola walteri, violet
Vitis rotundifolia, scuppernong
Zeuxine strateumatica, lawn orchid

APPENDIX 2

Vertebrate species documented as occurring (*) or expected to occur in Big Hammock.

AMPHIBIANS

Acris gryllus dorsalis, Florida cricket frog*
Ambystoma tigrinum tigrinum, Eastern tiger salamander
Amphiuma means, two-toed amphiuma*
Bufo quercicus, oak toad*
B. terrestris, southern toad*
Eleutherodactylus planirostris, greenhouse frog*
Gastrophryne carolinensis, Eastern narrow mouth toad*
Hyla cinerea, green treefrog*
H. gratiosa, barking treefrog*
H. ocularis, little grass frog*
H. squirrela, squirrel treefrog*
Pseudacrisnigrita verrucosa, Florida chorus frog*
Rana areolata aesopus, Florida gopher frog*
R. catesbiana, bullfrog*
R. clamitans, bronze frog*
R. grylio, pig frog*
R. sphenocephala, southern leopard frog*
Scaphiopus holbrooki, Eastern spadefoot

REPTILES

Agkistrodon piscivorus conanti, Florida cottonmouth
Alligator mississippiensis, American alligator*
Anolis carolinensis, green anole*
A. sagrei, Cuban anole
Cemophora coccinea coccinea, Florida scarlet snake
Coluber constrictor priapus, southern black racer*
Cnemidophorus sexlineatus sexlineatus, six-lined racerunner*
Crotalus adamanteus, eastern diamondback*
Deirochelys reticularia chrysea, Florida chicken turtle*
Drymarchon corais couperi, eastern indigo*
Elaphe guttata, corn snake
E. obsoleta quadrivittata, yellow rat snake*
Eumeces inexpectatus, southeastern five-lined skink*
Farancia abacura abacura, eastern mud snake
Gopherus polyphemus, gopher tortoise*
Heterodon simus, southern hog nose*
Kinosternon bauri, striped mud turtle*
K. subrubrum steindachneri, Florida mud turtle*
Lampropeltis getulus floridana, Florida kingsnake
L. triangulum elapsoides, scarlet kingsnake
Masticophis flagellum flagellum, eastern coachwhip
Micrurus fulvius fulvius, eastern coral snake*
Nerodia cyclopion floridana, Florida green water snake
N. fasciata pictiventris, Florida water snake*
Opheodrys aestivus, rough green snake
Pseudemys floridana peninsularis, peninsula cooter*
Rhineura floridana, Florida worm lizard
Sceloporus undulatus undulatus, southern fence lizard*
Scincella lateralis, ground skink*
Seminatrix pygaea pygaea, north Florida swamp snake
Sistrurus miliarius barbouri, dusky pigmy rattlesnake*
Stilosoma extenuatum, short-tailed snake
Storeria dekayi victa, Florida brown snake*
Tantilla relicta neilli, Florida crowned snake*

Terrapene carolina bauri, Florida box turtle*
Thamnophis sauritus sackeni, peninsula ribbon snake
T. sirtalis sirtalis, eastern garter snake

BIRDS

Accipiter cooperi, Cooper's Hawk
A. striatus, sharp shinned hawk
Agelaius phoeniceus, red winged blackbird*
Aix sponsa, wood duck *
Anhinga anhinga, anhinga*
Aramus guarauna, limpkin*
Archilochus colubris, ruby-throated hummingbird*
Ardea herodias, great blue heron*
Bombycilla cedrorum, cedar waxwing*
Bubo virginianus, great horned owl*
Bubulcus ibis, cattle egret*
Buteo lineatus, red shouldered hawk*
B. jamaicensis, red tailed hawk*
Butorides striatus, green heron*
Caprimulgus carolinensis, chuck-will's widow*
Cardinalis cardinalis, northern cardinal*
Casmerodius albus, great egret*
Cathartes aura, turkey vulture*
Catharus guttatus, hermit thrush*
Ceryle alcyon, belted kingfisher*
Chaetura pelagica, chimney swift*
Charadrius vociferus, killdeer*
Chordeiles minor, common nighthawk*
Circus cyaneus, northern harrier*
Colaptes auratus, northern flicker*
Colinus virginianus, northern bobwhite*
Columbina passerina, common ground dove*
Contopus virens, eastern wood pewee*
Coragyps atratus, black vulture*
Corvus brachyrhnchos, American crow*
C. ossifragus, fish crow*
Cyanocitta cristata, blue jay*
Dendrocopos villosus, hairy woodpecker*
Dendroica coronata, yellow rumped warbler*
D. dominica, yellow throated warbler*
D. palmarum, palm warbler*
D. pinus, pine warbler*
Dryocopus pileatus, pileated woodpecker*
Dumetella carolinensis, gray catbird*
Egretta caerulea, little blue heron*
E. thula, snowy egret
E. tricolor, tricolored heron*
Elanoides forficatus, American swallow tailed kite*
Eudocimus albus, white ibis
Falco sparverius, American kestrel*
Fulica americana, American coot*
Gallinula chloropus, common moorhen*
Geothlypis trichas, common yellowthroat*
Grus canadensis, sandhill crane*
Haliaeetus leucocephalus, southern bald eagle*
Hirundo rustica, barn swallow
Iridoprocne bicolor, tree swallow
Lanius ludovicianus, loggerhead shrike*
Meleagris gallopavo, wild turkey*
Melanerpes carolinus, red bellied woodpecker*
M. erythrocephalus, red headed woodpecker*
Melospiza melodia, song sparrow*
Mimus polyglottus, northern mockingbird*
Mniotilta varia, black & white warbler*
Myiarchus crinitus, great crested flycatcher*
Mycteria americana, wood stork*
Nyctanassa violacea, yellow crowned night heron*
Nycticorax nycticorax, black crowned night heron
Otis asio, eastern screech owl
Parus bicolor, tufted titmouse*
P. carolinensis, Carolina chickadee*
Passerina ciris, painted bunting*
Picoides pubescens, downy woodpecker*
P. villosus, hairy woodpecker*
Pipilo erythropthalmus, rufous-sided towhee*
Piranga rubra, summer tanager*
Podilymbus podiceps, pied billed grebe*
Polioptila caerulea, blue gray gnatcatcher*
Progna subus, purple martin*
Quiscalus quiscula, common grackle*
Regulus calendula, ruby crowned kinglet*
Sayornis phoebe, eastern phoebe*
Setophaga ruticilla, American redstart*
Sialia sialis, eastern bluebird*
Speotyto cunicularia, burrowing owl
Sphyrapicus varius, yellow-bellied sapsucker*
Spinus tristis, American goldfinch*
Strix varia, barred owl*
Sturnella magna, eastern meadowlark*
Tachycineta bicolor, tree swallow*
Thryothorus ludovicianus, Carolina wren*
Toxostoma rufus, brown thrasher*
Troglodytes aedon, house wren

Tytp alba, barn owl
Turdus migratorius, American robin*
Vireo griseus, white eyed vireo*
V. olivaceus, red eyed vireo
V. solitarius, solitary vireo*
Zenaida macroura, mourning dove*

MAMMALS

Blarina brevicauda, short-tailed shrew*
Canis latrans, coyote*
Condylura cristata, star-nosed mole*
Dasypus novemcinctus, 9-banded armadillo*
Didelphis virginiana, Virginia opossum*
Geomys pinetis, southeastern pocket gopher*
Glaucomys volans, southern flying squirrel*
Lasiuris seminolus, seminole bat*
Lynx rufus, bobcat*
Lutra canadensis, river otter
Mephitis mephitis, striped skunk*
Mus musculus, house mouse*
Myotis austroriparius, southeastern bat*
Nycticeius humeralis, evening bat*
Odocoileus virginianus, white-tailed deer*
Oryzimys palustris natator, rice rat
Peromyscus gossypinus, cotton mouse*
P. polionotus, old field mouse*
Podomys floridanus, Florida mouse*
Procyon lotor, raccoon*
Reithrodontomys humulis, eastern harvest mouse
Scalopus aquaticus, eastern mole*
Sciurus carolinensis, gray squirrel*
S. niger shermani, fox squirrel*
Sigmodon hispidus, hispid cotton rat*
Spilogale putorius, spotted skunk
Sus scrofa, feral pig*
Sylvilagus floridanus, eastern cottontail*
Tadarida brasiliensis, Brasilian free-tailed bat*
Urocyon cinereoargenteus, gray fox*
Ursus americanus floridanus, Florida black bear
Vulpes vulpes fulva, red fox*

MIGRATION OF LEAD ALONG DELANEY CREEK REGION OF TAMPA BAY

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ABSTRACT: *Analysis of water and soil samples at six different sites along Delaney Creek in Tampa, Florida, revealed lead contamination of the creek water. This contamination arises from migration of lead from a lead-acid battery disposal site at the junction of U. S. Highway 41 as it flows toward McKay Bay in Hillsborough County, Florida. Water samples from the creek nearest the battery disposal site were found to have a lead level of 2.90 ± 0.36 ppm, and creek bottom sampling detected a lead level at 269 ± 36 mg/kg air dry basis. Lesser levels of lead were found in the creek water up and down stream with 1.92 ± 0.36 ppm in water samples about 100 feet upstream and 1.17 ± 0.36 ppm in water samples about 500 feet downstream from the contamination site, indicating that some lead migration is occurring. At sites further upstream no lead was detected in the creek bottom samples.*

DELANEY CREEK passes through residential and industrial areas as it drains a Tampa watershed south of 22nd Street Causeway into the McKay Bay part of Tampa Bay. A lead-acid storage battery manufacturing and disposal site was located on the creek shoreline northwest of the Delaney Creek crossing of U.S. Highway 41. Lead contaminated soil from this plant site has been covered over with a layer of clean soil as a means of preventing human contact with the contamination. However, storm water runoff can still transport lead residues into the creek. Since the creek is subjected to tidal action, water can flow in both directions past the contamination site and distribute lead upstream as well as downstream. This study is intended to determine if there is any migration of lead upstream from the contamination site that could become a health hazard.

Several mechanisms can account for much of the lead migration away from the contamination site. Lead has been identified as one of the pollutants transported in water (Callahan et al., 1979). Lead solids can be transported by the creek and tidal currents. Migration of lead solids downstream has been observed in other creek contaminations (Watts, 1984). Lead and other heavy metals have been extracted from soil and transferred into stream waters (Fuhrer, 1986). Distribution of lead between the slightly soluble lead compounds at the creek site, the creek water and other creek sediments depends upon the physical and chemical characteristics of the soil and sed-

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TABLE 1. Location of sampling sites.

Site	Location
1	Rayleigh Street and Highway 41 where Delaney Creek crosses Highway 41.
2	Southeast of junction of Delaney Creek with Highway 41—Approximately 100 ft upstream from Site 1.
3	Near railroad trestle crossing Delaney Creek on the west side of Highway 41.
4	At bridge next to corner of 54th Street and 36th Avenue South.
5	Near railroad trestle crossing Delaney Creek between 54th Street and east of Highway 41.
6	Culvert for Delaney Creek crossing under 22nd Street Causeway near 74th Street.

iments (Chen, 1993). Biomethylation reactions to form organo-lead compounds by microbes could change the lead solubility and vapor pressure to make lead migration more favorable (Krishnamurthy, 1993). Naturally existing chelating agents in the creek sediments or creek water could increase lead solubility. Natural chelating agents have enhanced solubility of copper and other trace metals in west Florida streams (Martin et al., 1971).

Since Delaney Creek passes through residential neighborhoods upstream of the contamination, any migration of the lead upstream into the residential areas increases the potential for human contact and could become a health hazard. Elevated blood lead levels and lead poisoning, especially among children, are among the most common environmentally caused health problems in the United States (Center for Disease Control, 1985; and U.S. Senate Committee on Environment and Public Works, 1990). Adverse biological effects were identified for blood lead level as low as 1.0 ppm for heme-biosynthesis or 1.5 ppm for certain renal system effects and neurological alterations. Symptoms range from relatively subtle biochemical changes at blood lead levels below 1.0 ppm to severe retardation and even death at levels of 8–10 ppm. Lead can interfere with blood forming processes, vitamin D metabolism, kidney function; neurological processes and reproductive functions in both males and females.

METHODS—*Sampling*—Water and creek sediments were collected from six different sites along Delaney Creek. The sites are identified (Table 1 and Fig. 1). Samples were initially collected March 5, 1995. When the samples were taken from the creek, the current was slow, about 20 feet per minute. Sampling sites 1 and 2 are the closest sites for direct contamination of the creek from the battery disposal plant. Sample site 3 is located about ¼ mile downstream from the lead battery disposal site, while sample sites 2, 4, 5, and 6, are located upstream from the battery disposal site. Water samples were collected at the water surface near where the creek current was strongest in order not to disturb the soil bed of the creek. These samples were prepared for analysis immediately after returning to the laboratory. Sediment samples were collected by means of a 1-inch diameter PVC pipe inserted into the sediments and samples

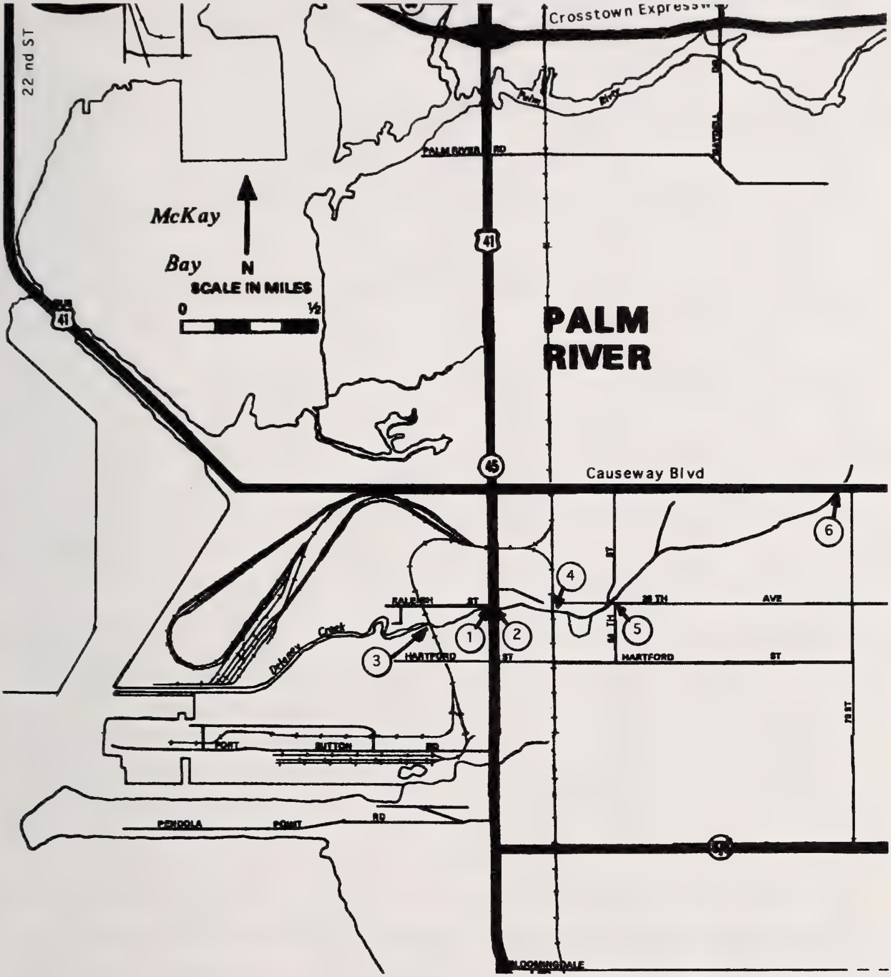

FIG. 1. Map showing the sampling sites along Delaney Creek.

about 2 inches thick were pulled out of the creek bottom near the shoreline. Soil samples were air dried and stored in sealed plastic bags prior to analysis. Additional water samples were collected March 20, 1997 at sites 1, 3 and 4 in order to monitor environmental remediation changes and verify the continued presence of lead. Analytical samples were prepared upon returning to the laboratory.

Analysis of samples—Samples were prepared for analysis following a procedure used in Hafen (1992) as follows. Water samples were collected in 1 gallon plastic containers and any suspended matter was allowed to settle. Specific gravity and pH measurements were made on water samples from each site as sampled, then each sample (one liter for each sample site) was treated with 1–2 ml of conc. HNO_3 (16M) and 5–6 ml of 3% H_2O_2 to liberate lead residues that might be bonded to other metals and organic materials in the water samples. Lead levels in each sample were then determined by means of atomic absorption measurements. Absorbances were compared to a standard curve to determine concentration.

TABLE 2. Distribution of lead along Delaney Creek.

Site No.	Lead in water (ppm) ± 0.36	Specific gravity	pH	Lead in sediment (mg/kg) ± 36
1	2.90	1.0002	7.52	269
2	1.92	1.0002	7.17	328
3	1.17	1.0002	7.42	82
4	0.98	1.0001	7.71	N.D.*
5	0.94	1.0001	7.73	N.D.
6	0.67	1.0001	7.61	N.D.

* Levels below 36 mg/kg.

Soil samples were dried at room temperature for two days. The soil samples were crushed to minus 18 mesh sieve size and one gram of each sample was treated with 10 mL of conc. HNO_3 to liberate lead from soil particles, and 5 mL of 3 % H_2O_2 to liberate lead from organic particles. After stirring samples about 5–10 minutes on a hot plate, 10 mL of deionized water was added to each sample, which was followed by the addition of 10 mL of conc. HCl (12M). Solutions were evaporated until the volumes became one half of the originals. After cooling soil sample solutions to room temperature, each of the soil sample solutions was diluted to near 100 mL in total volume and then filtered to remove any undissolved solids before final dilution to 100 mL in a volumetric flask.

Lead levels were determined at a wavelength of 216.7 nm initially on a Perkin-Elmer Model 460 atomic absorption spectrometer and then later on a Varian SpectrAA100 spectrometer for the recheck measurements. Standard solutions containing 1,2,3, 5, and 7 ppm lead were used for a standard curve: Absorption = 0.00558 [Pb] − 0.00342, $r^2 = 0.962$. Ten absorbance measurements of each sample were averaged in order to determine the lead values by means of the Perkin-Elmer AA Spectrometer. Qualitative anode stripping voltammetry measurements of the recheck samples were compared with the AAS data from the Varian spectrometer as a check on the low level values observed. Anode stripping voltammetry has been shown to be responsive to lead levels around 1 ppb.

RESULTS AND DISCUSSION—Some dissolved lead was present in the water upstream and downstream from the contamination site during the initial samplings, but lead in creek sediments was found only downstream from or near the contamination site where storm water runoff could be a factor. Sites upstream from the contamination source did not contain lead in the sediments at the detection level which was 36 mg/kg. Results from the initial samplings are summarized in Table 2. The creek water pH ranged from 7.2 to 7.7 and the amount of dissolved solids was sufficiently small to give a specific gravity near that of fresh water for all of the sites tested. On the basis of the salinity levels indicated by specific gravity results, tidal action would not appear to be a factor for upstream presence of lead in the water.

The observation of higher levels of lead in the sediments downstream relative to the upstream lead levels would be consistent with some transport of lead solids with creek current. This has been observed in studies of lead contamination in other rivers and streams (Watts, 1984). While site 2 is upstream by about 100 feet from the contamination site and located along a heavily traveled thoroughfare, the proximity for storm water runoff from

TABLE 3. Recheck of lead distribution along Delaney Creek.

Site No.	Lead in water (ppm)*	Specific gravity	pH
1	(0.020)	1.0001	7.08
3	(0.060)	1.0002	7.14
4	(0.035)	1.0001	8.45

* Estimated from AAS measurements on the Varian SpectrAA100 spectrometer. Measurements were below the calibration range.

the contamination site and/or from lead originating from the highway traffic flowing into the the creek at site 2 could account for the levels of lead observed in both creek water and creek sediments. Site 2 is not part of the remediation effort to stabilize the lead migration by covering the contaminated soil with clean soil.

At site locations 4, 5, and 6, lead was found only in the water samples and not in the sediment samples. These sites are further up stream and the lead levels were much lower than those near or downstream from the contamination site. This lead presence in the water was probably due to a combination of lead transport by wildlife in the stream and by contributions of stormwater runoff from the streets and railroad in the sections of the creek upstream from the main contamination site. Site 6 was located where the creek crosses the 22nd Street Causeway, a very heavily traveled road. Lead apparently from fuel residues has been found in soils adjacent to highways (Hafen, 1992) and could account for some lead presence in the water.

Remedial work carried out on the main contamination site (site 1) and on an upstream section of Delaney Creek between sites 4 and 5 during 1996 appear to have changed the lead migration patterns along the creek since the initial sampling in March of 1995. The course of the stream bed was modified by the insertion of a loop between sites 4 and 5. Additional creek water samples were collected at sites 1, 3, and 4 in March of 1997. These samples were analyzed, and lead levels were found to be much lower than the 0.6–3.0 ppm levels from previous samplings. These results are summarized in Table 3. These levels were found to be below the lower limits for optimum performance of atomic absorption spectrometry but qualitative anodic stripping voltammetry confirmed the small magnitude of lead concentration found to be approximately 10–50 ppb and the results from atomic absorption spectroscopy were used to calculate values. For these samplings lead was marginally detected upstream from the loop and do not pose a health hazard. An increase in alkalinity was observed in the second sampling of site 4. Upstream sites 4, 5, and 6 were slightly more alkaline (pH = 7.71, 7.73, 7.61) than downstream sites (pH = 7.52, 7.17, 7.42) in the initial sampling, and after the remediation work site 4 (pH = 8.45) is even more alkaline.

The near neutral pH along the length of Delaney Creek upstream and downstream from the contamination site suggests that the contamination site may not be the only source of lead. A low pH was observed downstream from the Sapp Battery Site along one of the streams feeding the Chipola River in the Florida panhandle (Watts 1992). Battery acid drained into the creek along with the lead contamination. Appreciable devastation was observed for several hundred yards downstream. The Sapp Battery Site was located away from thoroughfares and automotive exhaust lead would not be a contribution. In comparison the Delaney Creek pH is near neutral and the lead contributions from automotive exhausts could be part of the contamination source. Hafen (1992) has found lead along U. S. Interstate Highway 275 in Tampa, Florida that he attributed to leaded fuel residues.

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This list of Presidents of the Academy was compiled from past issues of the *Florida Scientist* and the journals that preceded it. Earlier compilations appeared in 1956 and 1961, and an update seems appropriate. There are some uncertainties in the listings that have appeared when several issues were combined, or a meeting was postponed, or perhaps the term of office was extended.

We are grateful for the assistance of Dr. Patricia M. Dooris and Ms. Geralyn Heartz. We will appreciate learning of additional information and/or corrections.

BBM
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REVIEW

Wunderlin, Richard P., *Guide to the Vascular Plants of Florida.* University Presses of Florida, Gainesville, 1998. Pp. x + 806 (hardcover). Price $35.00.

FLORIDA has one of the largest floras in North America. In spite of the incredible phytodiversity in the state, it also has one of the poorest floristic histories. For years, the only flora from the 1900s that included the state was John K. Small's (1933) *Flora of the Southeastern United States.*

Then, in 1971, Robert Long and Olga Lakela initiated a floristic renaisssance, partly because of the dubious quality of their *A Flora of Tropical Florida.* Another large impetus to floristics was because R. P. Wunderlin came to the state. Since his arrival, Dick has devoted most of his research to compiling a flora. For reasons that cannot be discussed here, the first volumes of the *Flora of Florida* are stalled in spite of being accepted by the state press years ago.

Meanwhile, Wunderlin produced his *Guide to the Vascular Plants of Central Florida* (1982) and Andy Clewell published *Guide to the Vascular Plants of the Florida Panhandle* (1985). More recently, Wunderlin and collaborators provided the CD-ROM *Atlas of Florida Vascular Plants* (1996). Those works left a gap in northeastern Florida that Dick has now filled. Moreover, this volume updates much of the material in previous contributions. He even scoops Kathy Burks and me on the arrival of *Ipomoea asarifolia* to Florida!

Although each species is given no more than four lines, this book still runs over 800 pages. In addition to keys to families, genera, and species, there is a standardized dataset for each species. Common names are used extensively, an interesting departure from his 1982 flora. For each species, he includes the scientific name with authorities, common name (rarely plural), habitat preference, frequency, region(s) of the state where it grows, reproduction period, and synonym(s). That is not much information about the varied biodiversity in Florida, but it is a good beginning.

Typically, I examined my favorite family, the Convolvulaceae, before anything else. The treatment is good, although not perfect. The keys work nicely, at least for me. There are, however, some clear errors –such as calling *Ipomoea violacea* the "heavenlyblue morningglory." That binomial has the common name "beach moonvine." The "heavenly blue" is *Ipomoea tricolor.* My avoidance of joining words in common names shows what I think of that practice, although some claim it to be a matter of taste or style. At least Wunderlin has followed the United States Department of Agriculture convention.

I would also argue that some species in the Convolvulaceae are not naturalized as indicated. "Blue daze" (*Evolvulus glomeratus*) does not, in my experience, spread either vegetatively or produce fruits in Florida, so how can it be naturalized? There are some similar examples in other families, but most are correct.

He has missed at least one species that has been in southern Florida for about a decade—*Euphorbia oerstediana* (Klotzsch & Garcke) Boiss. This is another example of weeds being accidentally introduced as contaminants of cultivated plants, and then distributed with landscape plants. This herb occurs in many (most?) landscaped areas in southeastern Florida.

Others using this new flora will also find problems. Yet, floras are status reports, and this contribution to Florida botany is long overdue. This book could have been improved if it had circulated treatments to specialists for their comments. However, that process depends on the timely replies of colleagues, and these often are not forthcoming.

I congratulate Wunderlin on completion of this book. His treatise brings us light years from 1982 (as we verge on a twenty-first century) toward an understanding of what we have, and what we had, in the state. He also shows us what we stand to lose to exotic species invasions, urbanization, and similar impacts of modern civilization.—Daniel F. Austin, Department of Biological Sciences, Florida Atlantic University, Boca Raton, 33431.

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FLORIDA SCIENTIST

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Biological Sciences

EFFECT OF SALINITY ON THE GROWTH OF *VALLISNERIA AMERICANA* MICHX. FROM THE CALOOSAHATCHEE ESTUARY, FLORIDA

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ABSTRACT: *The effects of salinity on the growth and survival of wild celery,* Vallisneria americana *Michx., from the Caloosahatchee Estuary (southwest Florida, USA), were examined experimentally using indoor mesocosms. Plants were exposed to 5 constant salinity treatments (0‰, 3‰, 9‰, 12‰, 15‰) for 43 days. Two factors (position in the estuary, season) which might lead to different exposure regimes and hence different salinity tolerances were also examined. Two independent experiments were conducted: one during the winter dry season and one during the summer wet season. In both seasons, plants were collected from two sites, one 5.5 km upstream of the other. The nutrient and chlorophyll concentrations in the plant tissue were analyzed at both sites. Salinity effects did not vary as a function of site, however, plants grown in sediment from the more upstream site had a higher concentration of phosphorus in blades. There was no seasonal effect on salinity tolerance limits. In both seasons, plants survived exposure to 15‰ for 43 days and net production of blades ceased at this salinity. There were seasonal differences in the pattern of response to salinity. Growth, as measured by blade elongation and production of blades and shoots, exhibited a threshold response in the dry season, with growth higher at salinities less than or equal to 3‰ and lower at salinities greater than or equal to 9‰ ($0 = 3 > 9 = 12 = 15$‰). In the wet season, growth declined monotonically with increasing salinity ($0 > 3 > 9 > 12 > 15$‰). At salinities ≤ 9‰, growth was greater during the wet season than during the dry season. Depending on the parameter, seasonal differences disappeared at 12 or 15‰.*

BEDS of submersed aquatic angiosperms are ecologically important in shallow lotic, estuarine, and marine habitats because they provide shelter and food for many benthic and pelagic organisms and form nursery habitat for early life stages of numerous commercially important fish and shellfish. They also enhance sediment deposition and retard erosion and resuspension (Thayer et al., 1984; Kemp et al., 1984; Killgore et al., 1989; Carter et al., 1988; Lubbers et al., 1990).

No species of submersed aquatic angiosperm is strictly limited to waters of estuarine salinities. Typically, marine species dominate higher salinity regions (> 20‰) while salt-tolerant freshwater species inhabit the lower salinity regions (Kemp et al., 1984). Establishing the effects of salinity on these freshwater species is key to understanding their occurrence, distribution, abundance, and performance in estuarine systems.

Wild celery, *Vallisneria americana* Michx., is a salt-tolerant freshwater species that often occurs in the fresh, oligohaline, and mesohaline reaches of estuaries in the Northeastern and Southeastern United States (Bourn, 1932; Lowden, 1982). It is dioecious, perennial, and capable of extensive clonal growth through the formation of stolons (Lovett-Doust and Laporte, 1991). Northern populations overwinter as a dormant winter bud buried in the sediments and the above-ground biomass disintegrates (Titus and Hoover, 1991). In south Florida, populations do not completely die back in winter (Dawes and Lawerence, 1989). Actively growing plants may be found all year.

While there have been several determinations of the salinity tolerance of *V. americana* (Bourn, 1932; 1934; Haller et al., 1974; Twilley and Barko, 1990) estimates do not agree and there is little information concerning factors which might modify salinity tolerance. Bourn (1932;1934) investigated potential seasonal differences in salinity tolerance of plants collected from Back Bay, Virginia and found none. Twilley and Barko (1990) compared tolerances of plants (collected from the Potomac River, Virginia) grown at high (50% incident solar radiation) and low (8% incident solar radiation) light levels and found no differences.

In estuaries, salinity typically varies temporally. The effects of such variation on the salinity tolerance of salt-tolerant freshwater species have not been investigated. In subtropical South Florida, there is a prominent seasonal cycle in estuarine salinity driven by wet season (May–October)–dry season (November–April) differences in rainfall and runoff. Plants growing at the end of the wet season may have experienced an antecedent exposure to lower salinity than those surviving at the end of the dry season when salinities are higher. Estuaries are also typified by spatial variation in salinity, sediments and other environmental factors. Salinity tolerance might vary spatially owing to different salinity exposure or other differences between sites. For example, site differences in growth and chemical composition of *V. americana* have often been attributed to contrasting sediment types (Titus and Stephens, 1983; Rybicki and Carter, 1986; Rogers et al., 1995). Here, we examine the salinity tolerance of *V. americana* collected

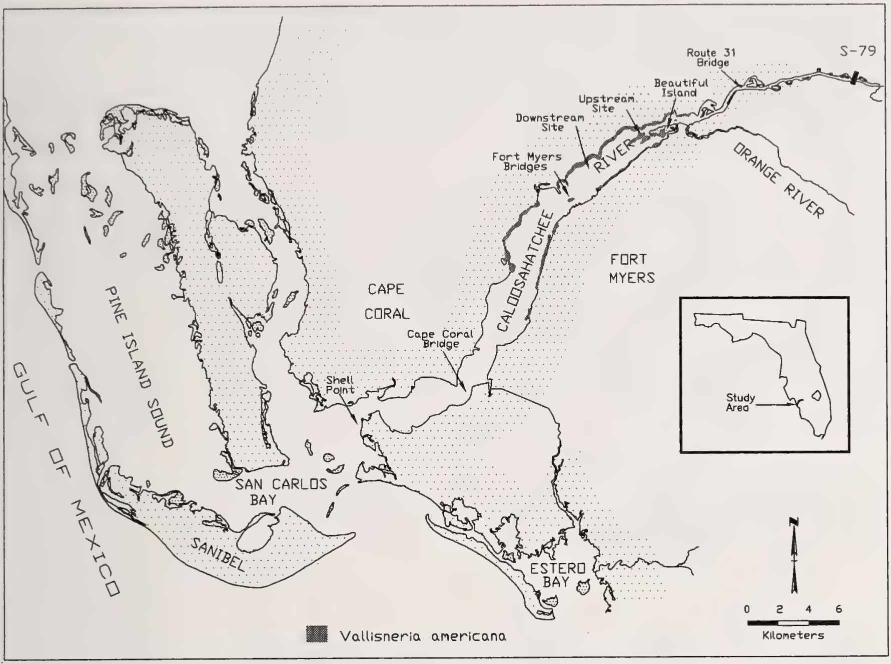
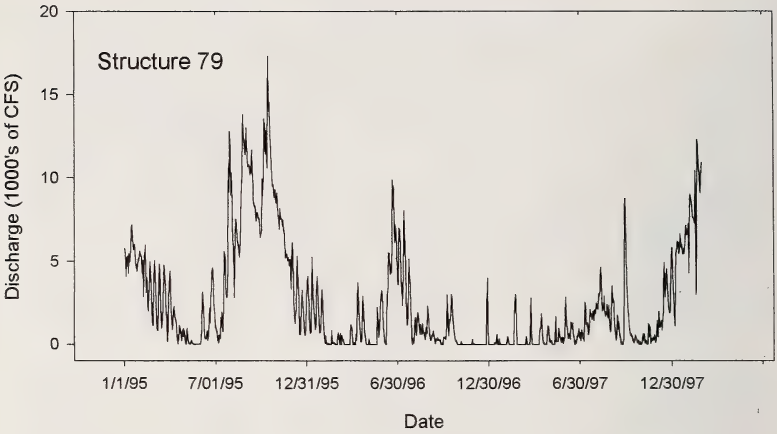


FIG. 1. The distribution of *Vallisneria americana* in the Caloosahatchee Estuary. Also shown are the sites from which *Vallisneria* was collected and the location of salinity recorders at the Route 31 and Ft. Myers bridges maintained by the South Florida Water Management District.

from the Caloosahatchee Estuary in South Florida and consider effects of season and position in the estuary.

STUDY AREA—The Caloosahatchee Estuary is located on the Southwest Coast of Florida, USA (Fig. 1). The major source of freshwater to the estuary is the Caloosahatchee River which runs 65 km from Lake Okeechobee to the Franklin Lock and Dam (S-79, Fig. 1). Beds of *V. americana* can occur up to 30 km downstream of S-79 but grow most luxuriantly upstream of the Ft. Myers bridges, especially around Beautiful Island (Fig. 1, Hoffacker, 1994). The beds may be important habitat for fish and shellfish as described previously and also may comprise a food source for a resident population of West Indian manatees (*Trichechus manatus*). *V. americana* can be a major dietary component of the manatee and is sometimes preferred over other submersed aquatic vegetation (Packard, 1981). Anecdotal and qualitative observations indicate that in some years beds may be extensive and quite lush in both seasons, while in other years, only sparse populations of small plants may be found.

The magnitude of freshwater discharge at S-79 varies temporally (Fig. 2). As data from continuous salinity recorders in the downstream estuary show, this variability causes salinity upstream of the Ft. Myers bridges to vary on several time scales (Fig. 2). During the winter dry season, upstream intrusion of seawater causes salinity to exceed the tolerance limits for *V. americana* reported in the literature (up to 12‰; Twilley and Barko, 1990). In the summer wet season, discharge can turn the system entirely fresh. The record also shows considerable variation in the magnitude and duration of these seasonal intrusions of saltwater. On shorter time scales (3–7 days) salinity can change rapidly. Rates of 1‰/day at Bridge 31 and 2‰/day at


Structure 79
Discharge (1000's of CFS)
20
15
10
5
0
1/1/95
7/01/95
12/31/95
6/30/96
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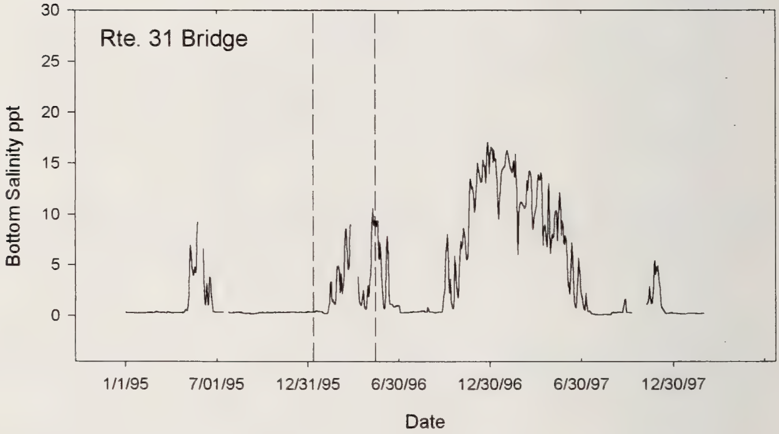
12/30/97
Date


Rte. 31 Bridge
Bottom Salinity ppt
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12/31/95
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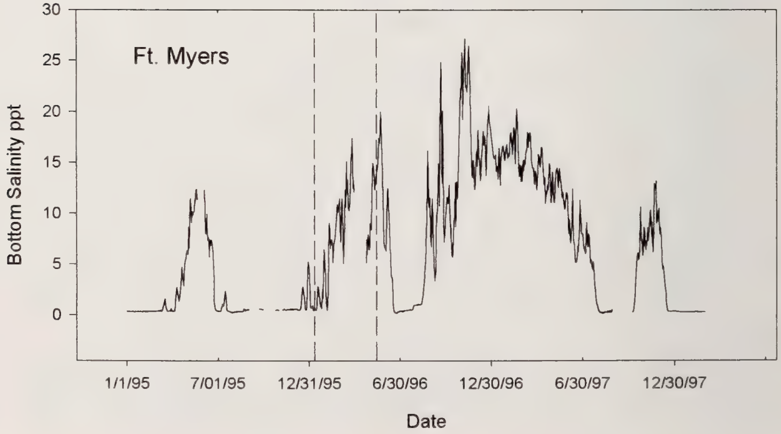
12/30/96
6/30/97
12/30/97
Date


Ft. Myers
Bottom Salinity ppt
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the Ft. Myers bridges are common in the record. The record also shows that during the dry season, salinity varies spatially. This study was undertaken 1) to determine the influence of salinity on the growth and survival of V. americana 2) to better understand the effects of freshwater discharge and attendant salinity variation on the distribution and abundance of *V. americana* and 3) to help identify the level of freshwater discharge at S-79 required to maintain *V. americana* upstream of the Ft. Myers bridges.

MATERIALS AND METHODS—A mesocosm approach was used to examine the influence of salinity on the growth and survival of *V. americana.* Plants were grown in ten cylindrical tanks (1.3 m in diameter × 1 m deep) filled with water to a depth of 60 cm (volume = 800 l). The tanks were located indoors at an aquarium facility at the Gumbo Limbo Nature Center in Boca Raton, FL. A 1000 Watt metal halide lamp, kept on a L:D photoperiod of 12:12 h, supplied light to each tank. A given salinity was maintained by mixing appropriate volumes of fresh and salt water (total volume = 114 l) from each of two head tanks located above each mesocosm. Head tanks were alternately filled and emptied into the mesocosms using solenoid valves controlled by timers. Thus, water was delivered to the mesocosms in a series of 114-liter pulses. Water in the mesocosms was replaced 3 times daily. Salt water was pumped from the Atlantic Ocean. Tap water, passed through a series of activated charcoal towers and filters (20 micron pore size) to remove chlorine, was used as a source of fresh water. Seasonal variation in salinity tolerance was examined by conducting two experiments: one during the dry season (Nov.–April) and one during the wet season (May–Oct.). Similar methods, summarized below, were employed during each experiment.

Collection of plants—To examine spatial variation in salinity tolerance, *V. americana* and associated sediments were collected from each of two locations in the Caloosahatchee Estuary (Fig. 1). The downstream site was located near North Fort Myers (Lat: 26° 40′ 0.92″ N, Long: 81° 52′ 20.77″ W). The other site was approximately 5.5 km upstream. Plastic, rectangular tubs (14 cm H × 24 cm L × 15 cm W) were filled with sediment in the field. Sediment was collected with a shovel and passed through a 0.25 cm^2 mesh screen, to remove shells, pebbles, and large infauna. Plants were collected as plugs from cores taken with a post hole digger. Each plug consisted of one rosette and its root material surrounded by 30–40 ml of sediment from the site of collection. Plant plugs were placed in ice chests, covered with water from the site, and transported back to the laboratory on the day of their collection. The dry season collection occurred on 11 January, 1996, before the major seasonal intrusion of salt water (Fig. 2). The wet season collection occurred on 15 May, 1996, before summer runoff washed salt from the system (Fig. 2).

Salinity experiments—Upon return to the laboratory, plants and sediments were allotted to 4 treatment combinations and distributed to the mesocosms as follows: upstream plants in upstream sediments (2 tubs/mesocosm), downstream plants in downstream sediment (2 tubs/mesocosm), upstream plants in downstream sediment (1 tub/mesocosm), and downstream plants in upstream sediments (1 tub/mesocosm). Four plant-plugs, including 30–40 ml of sediment from the site of collection, were planted in each tub.

After a six-week acclimation period in fresh water, shoots produced since initial planting were removed to standardize initial conditions. To reflect conditions in the field, salinities were gradually raised (1.5‰/day) to final treatment salinities of (0‰, 3‰, 9‰, 12‰ and 15‰). Two mesocosms were randomly assigned to each salinity treatment. Plants were held at treat-

←

FIG. 2. Daily average freshwater discharge (cfs) at the Franklin Lock and Dam (S-79) and salinity at the Route 31 and Ft. Myers bridges from records maintained by the South Florida Water Management District. Dashed lines mark the days upon which plants were collected.

ment salinities for 43 days. The dry season experiment commenced on March 1, 1996, and the wet season experiment on July 11, 1996. Tanks were scrubbed as necessary to remove wall growth. Once a week, epiphytic growth was gently removed by hand from plant blades. Salinity and temperature were monitored daily with a YSI 600XL data sonde. PAR was checked weekly with a LICOR spherical quantum sensor and data logger and adjusted to 475–525 μmol photons/m²/sec at the bottom of the tank by raising or lowering the lamp. Water samples were analyzed weekly for dissolved inorganic nitrogen and phosphorus on an Alpkem Auto Analyzer (APHA, 1985; SFWMD, 1994).

Plant response variables—The following non-destructive measurements were made weekly during each experiment: number of shoots per tub, number of blades per shoot, and blade length of 30 randomly selected blades per tub. In addition, one new blade in each tub was marked with a piece of thread sewn through the blade. Lengths were measured at the time of marking and after one week.

The oxygen metabolism of *V. americana* blades was measured at the end of the wet and dry season experiments. At least two blades were removed at the sediment surface from each tub of the site treatments (excluding cross plants). These were placed in clear and opaque 300 ml BOD bottles and returned to the bottom of each tank for a 15 min acclimation period. Initial dissolved oxygen (DO) was measured in each bottle with an Orbisphere model 2607 oxygen meter equipped with a miniature sensing head (model 2112). Light and dark incubations lasted approximately 60 and 120 minutes, respectively, after which final DO was measured in each bottle. Blades were removed from each bottle, dried at 80 °C, and weighed for dry mass. DO evolved during the incubations was normalized per unit dry mass. Because dark bottle results were variable and often showed oxygen evolution, only net primary production data, calculated from the light bottles, were analyzed.

At the end of each experiment, plants were harvested from each tub. Three 0.5 cm² sections of blade from each tub were frozen for chlorophyll *a* analysis. Blades were dried to constant weight at 80 °C and ground to a fine powder for determination of nitrogen and phosphorus content.

Samples for chlorophyll *a* analysis were ground in 90% acetone and extracted at 0 °C for three hours. Chlorophyll *a* concentration was determined spectrophotometrically on a Perkin Elmer UV/VIS Lambda 12 spectrophotomter (APHA, 1985; SFWMD, 1994). Tissue nitrogen was determined by elemental analysis on a Fissons CNS Analyzer Series 2 against a BBOT ($C_{26}H_{26}N_2O_2S$) standard. Analytical replicability was ± 5%. Recovery of NIS reference material was 95–104% for nitrogen in peach and spinach leaves. Tissue P was analyzed by a method modified from Solorzano and Sharp (1980). Ground 50 mg samples were ashed (550 °C) and hydrolyzed at 80 °C with 0.025 *N* HCl. Hydrolyzed samples were diluted 1:100 with distilled water and analyzed for soluble reactive phosphorus on an Alpkem Auto Analyzer. Analytical replicability was ± 5%, and recovery of P from NIS reference material was 88–104% for both peach and spinach leaves.

Statistical analysis—The experimental design included four factors: season (wet or dry), site (upstream plants and sediment or downstream plants and sediment), salinity (0, 3, 9, 12, 15‰) and replicate (the two mesocosms at each salinity). The cross-planted tubs (upstream plants in downstream sediments and downstream plants in upstream sediments) were included to help explain differences between sites only if these were statistically detected. Cross-planted tubs were omitted from the initial analysis of the data.

To avoid pseudoreplication, data taken on a given day in each mesocosm were averaged across the two tubs from each site. This procedure yielded one observation from each of the two mesocosms assigned to each site × salinity combination. A four factor ANOVA, with interaction, was used to statistically evaluate the data taken at the end (Day 43) of the experiment. For non-destructive measurements, data taken on Day 1 of the experiment were similarly analyzed. The replicate factor (two mesocosm tanks assigned to each salinity) was considered to be random and nested with the salinity factor. In such a design, the replicate mesocosm is the experimental unit. Rules for determining F-tests in nested ANOVA designs are summarized in Winer (1971). Differences between main effect and interaction means were evaluated with the Student-Newman-Keuls test (Winer, 1971).

Blade elongation rates measured by marking newly formed blades with a thread were analyzed differently. The marking technique was not 100% effective for two reasons: threads often worked their way out of a leaf and at times, the narrow width of blades precluded marking in the first place. As a result during some weeks not all mesocosms contained marked leaves. To ensure a more balanced design, the mesocosm factor was dropped and data taken over the entire course of the experiment were evaluated using a 3-factor (Season, Site, Salinity) ANOVA with interaction. All statistical analyses were accomplished using SAS Version 6 (SAS, 1989).

The ANOVA approach examines the relative differences between treatments but does not quantify growth rates. Weekly measurements were used to determine net rates of blade production, shoot production, and change in average blade length. Growth was modeled using the exponential growth equation ($N_t = N_0e^{rt}$). Again, data taken on a given day in each mesocosm were averaged across the two tubs from each site. Regressions were calculated for each salinity treatment.

RESULTS—With few exceptions, measured salinities over the course of both experiments were maintained within ±1‰ of nominal treatment salinities (Fig. 3). Temperature in the ten mesocosms varied by ± 2 °C at any one time and averaged (all ten tanks) 25.2 ± 0.8 °C during the dry season and 27.2 ± 0.9 °C during the wet season. Three-way ANOVA (season, salinity, replicate) revealed that in all salinity treatments, temperatures were higher in the wet season than in the dry season ($p<0.05$). Dissolved inorganic nitrogen (DIN) concentrations were about 10 μmol higher in the dry than the wet season (Table 1). In contrast, dissolved inorganic phosphorus (DIP) was slightly higher in the wet season than the dry season. Both DIN and DIP declined with increasing salinity.

Morphometric measurements—At the beginning (Day 1) of the two experiments, conditions were similar in each salinity treatment. Tubs in each of the mesocosms averaged about 4 shoots/tub, with 10 to 14 blades/shoot and blades 3 to 4 cm in length ($p>0.05$ for main effect of salinity, and $p>0.05$ for all interaction terms involving salinity) . There were some statistical differences associated with the site factor. At the beginning of the wet season experiment, plants from the upstream site had more blades per shoot (about 13) and longer blades (3.9 cm) than plants from the other three season × site combinations (11–12 blades/shoot, 2.9–3.1 cm in length). Because the site factor was completely crossed with the salinity factor, these site differences were independent of salinity and do not affect experimental results for salinity.

After 43 days, no site effects were detected. However, a significant interaction between season and salinity was detected ($p < 0.05$) for average blade length, number of blades/tub, and number of shoots/tub. There were differences in the response of *V. americana* to salinity in the two seasons. In the dry season, number of blades and number of shoots exhibited a threshold response with greater production at 0‰ and 3‰ than at higher salinities.

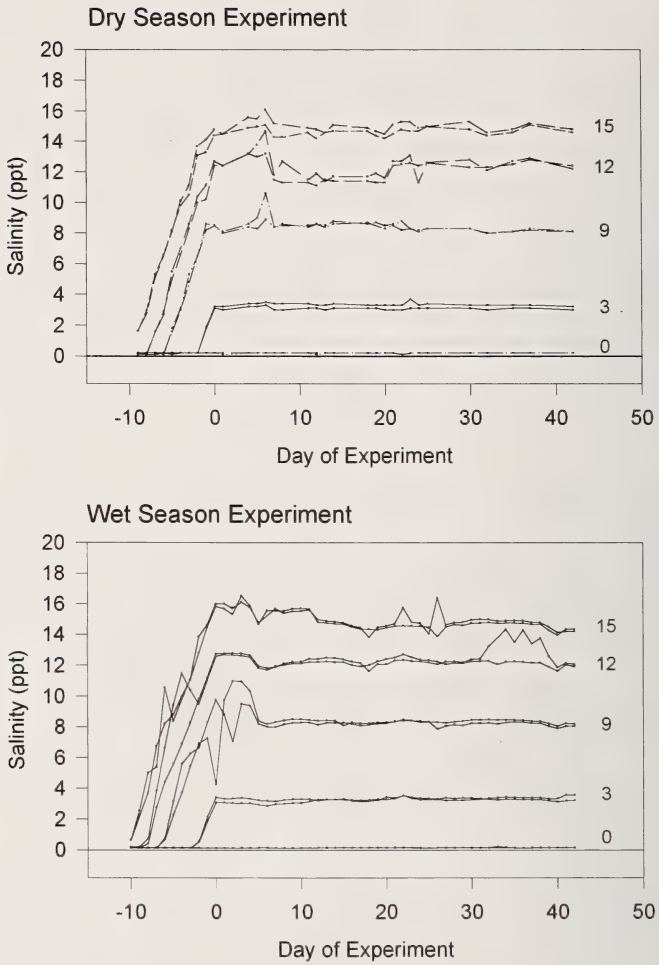

FIG. 3. Time course of salinity in the mesocosms during the two seasonal experiments.

Blade length did not vary with salinity. In the wet season, blade length, number of blades, and number of shoots all decreased with increasing salinity. The statistical differences between specific treatment means (Fig. 4) were slightly different for each parameter, but all showed the same general pattern.

Seasonal differences also varied as a function of salinity. At 0‰, 3‰, and 9‰, the number of blades and shoots produced was higher in the wet season than in the dry season and blades were longer ($p < 0.05$, Fig. 4). Seasonal differences disappeared at 12 and 15‰ (Fig. 4).

Rates of growth—Elongation rates (cm/day) of newly formed blades measured by marking with a thread also varied with salinity and season

TABLE 1. Average concentrations of dissolved inorganic nitrogen (DIN = NH_4 + NO_2 + NO_3) and dissolved inorganic phosphorus in the two mesocosms assigned to each salinity. Units are μmole/l.

	Dry season		Wet season	
Salinity	DIN	DIP	DIN	DIP
0	35.5 ± 4.5	2.6 ± 2.1	22.8 ± 4.5	3.1 ± 0.4
	37.8 ± 5.5	2.6 ± 2.1	21.2 ± 3.5	3.3 ± 0.3
3	34.1 ± 4.0	1.9 ± 1.8	21.6 ± 3.0	3.2 ± 0.4
	35.1 ± 4.0	2.5 ± 2.0	24.2 ± 2.7	3.2 ± 0.5
9	31.0 ± 3.7	2.2 ± 1.8	19.5 ± 3.2	3.2 ± 0.5
	31.4 ± 3.7	2.3 ± 1.8	20.5 ± 3.0	2.9 ± 0.3
12	30.4 ± 3.8	2.0 ± 1.6	17.2 ± 1.9	2.5 ± 0.3
	27.5 ± 3.6	2.0 ± 1.6	17.1 ± 1.8	2.5 ± 0.4
15	27.0 ± 3.1	1.8 ± 1.4	16.5 ± 4.1	2.2 ± 0.2
	22.1 ± 6.9	1.7 ± 1.4	14.9 ± 2.1	2.3 ± 0.2

(Fig. 5). During the winter dry season, there were significant differences between salinity treatments. However, elongation rates did not vary with salinity in any regular way. Blades grew as fast at 15‰ as they did at 0‰. During the wet season, growth rates declined with increasing salinity being highest in freshwater, somewhat lower at 3‰, and markedly reduced at 9, 12 and 15‰. Seasonally, wet season growth rates were higher at 0, 3, and 9‰. No seasonal differences were found at 12 or 15‰.

Significant positive net production of shoots, calculated from weekly counts, occurred at all salinities (Table 2). By contrast, net production of blades ceased at 15‰ in both seasons (Table 2). In the dry season, rates of increase in average blade length were significantly greater than zero ($p<0.05$) at all salinities. In the wet season, average length actually decreased at 15‰ (Table 2). Within each season lowest rates of shoot production, blade production, and change in blade length were found at 15‰. Highest rates occurred at 0 and 3 ‰.

Measurements of instantaneous oxygen production by excised leaves were quite variable and ANOVA revealed no significant effects of season or salinity. However, a linear regression of net primary production on salinity including all 80 data points was significant. The relationship (O_2/mg dry mass/hr $= -0.002(\text{Salinity}) + 0.044$, $p < 0.01$) suggested a negative effect of salinity on production and explained 20% of the total variation.

Chemical composition—The concentration of nitrogen in blades ranged from 19 to 31 mg N/gm dry wt. Concentration decreased with increasing salinity in both seasons but the pattern was significant only in the wet season (Fig. 6). Phosphorus in blades ranged from 2.3 to 5.2 mg P/gm dry wt and varied with season and salinity in a manner similar to nitrogen. N:P atomic ratios ranged from 20 to 24 in the dry season and from 14 to 19 in wet

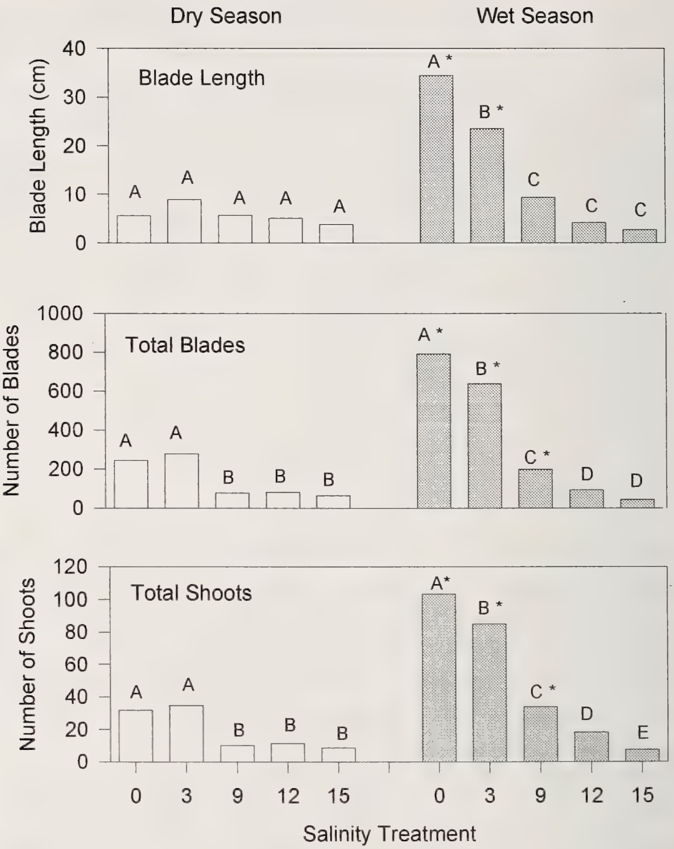

FIG. 4. Average blade length, number of blades and number of shoots per tub in the salinity treatments. Letters indicate statistical differences between salinity treatments in each season. Means with different letters are statistically different at $p<0.05$. Asterisk (*) indicates a significant difference ($p<0.05$) between seasons at a particular salinity.

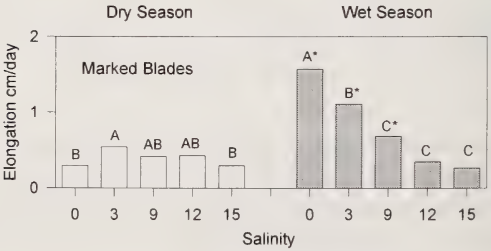

FIG. 5. Elongation rates of individual marked blades in the salinity treatments. Letters and asterisk are as in Fig. 4.

TABLE 2. Exponential growth coefficients, r, (95% CI) for total blades, total shoots and average blade length in two seasons (wet, dry) and 5 salinity treatments. ns = not statistically different from zero.

			Salinity	Treatment (‰)		
Attribute	Season	0	3	9	12	15
Blades	Dry	0.046 (0.003)	0.042 (0.009)	0.013 (0.007)	0.013 (0.003)	0.009 (0.010)ns
	Wet	0.071 (0.004)	0.061 (0.004)	0.032 (0.004)	0.015 (0.006)	−0.002 (0.006)ns
Shoots	Dry	0.053 (0.003)	0.054 (0.007)	0.021 (0.008)	0.027 (0.002)	0.018 (0.013)
	Wet	0.081 (0.006)	0.071 (0.005)	0.052 (0.006)	0.036 (0.008)	0.012 (0.008)
Average length	Dry	0.010 (0.005)	0.027 (0.004)	0.015 (0.004)	0.012 (0.003)	0.006 (0.003)
	Wet	0.054 (0.003)	0.042 (0.005)	0.019 (0.003)	0.004 (0.003)	−0.006 (0.005)

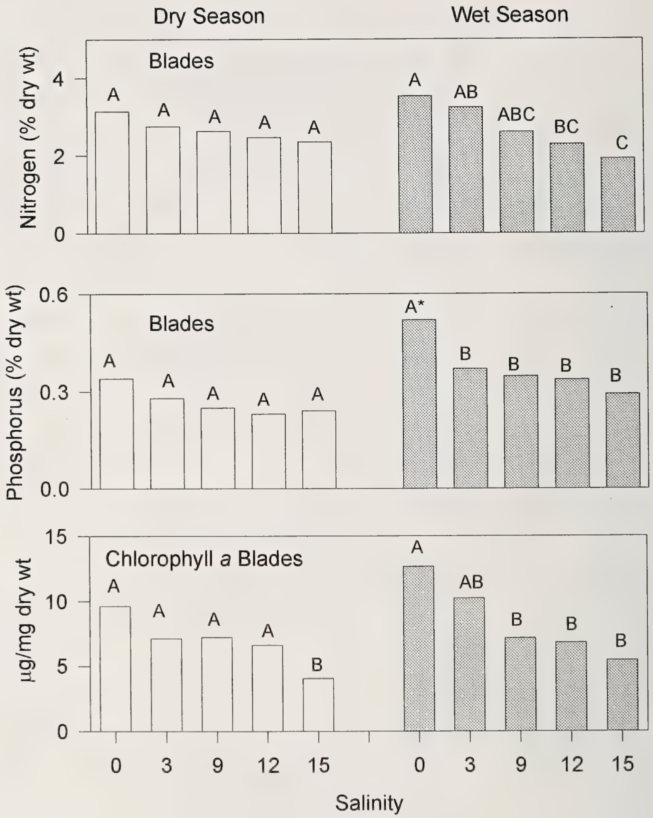

FIG. 6. Average concentration of nitrogen, phosphorus and Chlorophyll *a* in blades of *Vallisneria americana* in each salinity treatment. Letters and asterisk are as in Fig. 4.

season with no differences between salinities. The concentration of chlorophyll *a* in blades decreased with increasing salinity in both seasons.

Site effects—The chemical composition of *V. americana* was affected by position in the estuary. Overall, blades from downstream plants, growing in downstream sediments, had higher N:P ratios (atomic) than blades from upstream plants growing in upstream sediments (21.8 vs 16.9 for blades; main effect F-test, $p < 0.01$, interactions with site factor not significant). This difference was significant even if data from the two seasons were analyzed separately. The difference in N:P ratio was due to higher phosphorus concentrations in blades from the upstream site. Nitrogen concentration in blades did not differ between sites ($p > 0.05$) whereas phosphorus in blades from the upstream site (3.6 mg P/gm dry wt) was greater than in plants from the downstream site (2.8 mg P/gm dry wt; main effect F-test $p < 0.01$ in both cases, interactions with site factor not significant). These differences were statistically significant when the data for each season were analyzed separately.

Reanalysis of the data to include the cross planted treatments as additional levels of the site factor clearly showed that the concentration of P in blades varied as a function of the sediment in which the plants were grown (main effect F-test, $p < 0.01$; interactions with site factor not significant). Results of the SNK test revealed that the treatment means fell into two groups according to the type of sediment in which plants were grown: upstream plants in upstream sediments (3.6 mg P/gm dry wt) = downstream plants in upstream sediments (3.5 mg P/gm dry wt) > downstream plants in downstream sediments (2.8 mg P/gm dry wt) = upstream plants in downstream sediment (2.8 mg P/gm dry wt). These results suggest that differences between sediments from the two sites account for the compositional differences between plants.

DISCUSSION—The ecological impacts of salinity variations are difficult to assess because other factors, such as nutrient concentration, can co-vary with salinity even under the controlled conditions used here. The mixing of ocean water and municipal fresh water in our experiment resulted in nutrient concentrations which decreased with increasing salinity (Table 1) but not to concentrations likely to have limited growth. In addition, blade tissue concentrations exceeded the levels associated with nutrient limited growth (1.3 N % dry wt and 0.13 P % dry wt) established by Gerloff and Krombholz (1966). Light also was not confounded with salinity since it was maintained at levels greater than the I_{sat} of 200 μmol photons/m^2/sec for *V. americana* (Harley and Findlay, 1994).

Salinity tolerance—Salinity tolerances of *V. americana* reported in the literature vary. Bourn (1932, 1934) examined material from Back Bay, VA. In both winter and summer experiments, growth declined with salinity and ceased at 8.4‰. Haller and co-workers (1974) collected plants from canals in Ft. Lauderdale, FL. They reported growth at 0.17‰ and 3.33‰, no growth after 4 weeks at 6.66‰ or 10‰ and death at 13.3‰ and 16.6‰. Twilley and Barko (1990) grew *V. americana,* collected from the Potomac River, VA for five weeks and found no effect of salinity on growth over the range 0‰ to 12‰. They attributed this to the method of exposure. They slowly raised (1.5–2‰/day) salinities to treatment levels over a period of days, whereas in previous studies, plants were transferred directly to treatment salinities and acutely exposed to high salinity.

V. americana from the Caloosahatchee Estuary survived 6 weeks exposure to 15‰ in both seasons: a higher salinity than has heretofore been reported. At 15‰ growth continued at a slow rate for some parameters (e.g. number of shoots) but increases in total number of blades ceased in both seasons. Additionally, average blade length declined during the summer wet season. A salinity of 15‰ is at or near the upper tolerance limit for growth in the Caloosahatchee. Although the pattern of response differed in the two seasons (threshold in winter, steady decline in summer), the general finding of decreasing growth with increasing salinity is consistent with the results of Haller and co-workers (1974) and Bourn (1932, 1934). Like Twilley and Barko (1990), we raised the salinity slowly (1.5‰/day) to treatment levels over a period of days. Method of exposure may not explain all differences between studies.

An alternative explanation is that there are real differences in salinity tolerances among populations of *V. americana. V. americana* does exhibit substantial morphological variation in inflorescence structure and growth form (Lowden, 1982). There may also be substantial physiological and genetic variability, which could account for the reported differences in salinity tolerance summarized here. A comparative study, testing this hypothesis, has not been done.

Although there were seasonal differences in growth in the lower salinity treatments (0–9‰), we found no evidence that overall salinity tolerance limits varied seasonally. For example, the salinity at which growth ceased or at which plants could no longer survive did not vary seasonally. Despite very different exposure regimes prior to the two experiments (Fig. 2) , *V. americana* survived and, for all but one parameter (change in average blade length; Table 2) , responded similarly at 15‰ in both seasons.

As has been found in other studies of *V. americana* from Florida (Dawes and Lawrence, 1989), growth occurred in both seasons with higher growth rates in summer than in winter (Table 2). The winter 'die back', typical of more northern populations (North Carolina: Zamuda, 1976; Pennsylvania/ New York: Sullivan and Titus, 1996; Maryland: Rybicki and Carter, 1986; Wisconsin: Donnermeyer and Smart, 1985) is not complete in central and south Florida (Dawes and Lawrence, 1989) and actively growing rosettes may be found all year.

The growth of *V. americana* is influenced by temperature (Zamuda, 1976; Biernaki et al., 1997). Relatively warm temperatures could account for winter growth in southern locations. Even though the seasonal difference in temperature that we observed was small (about 2 °C), this in part may account for the higher wet season growth in our experiment. Our results indicate that increasing salinity decreases the seasonal difference in growth until it disappears at 12 to 15‰.

Position in the estuary (upstream vs downstream) also did not affect salinity tolerance despite the potential for different exposure regimes. Although we did not measure salinity at the two collection sites during our experiment, the data in Fig. 2 suggest a difference in salinity. In 1996 and 1997, Kraemer and co-workers (1998) measured salinity on 10 occasions during each season at the downstream collection site and at a site 100 yards south but adjacent to the upstream site. During the wet season salinity was similar at each site (paired t-test, $p > 0.05$, $n = 10$). During the dry season the salinity difference was only about 2 ‰ (13.5‰ downstream vs 11.7‰

upstream, paired t-test $p < 0.05$, $n = 10$) and probably too small to cause any difference in tolerance. While differences between sediments from the two sites may have affected *V. americana*'s chemical composition, no evidence for a site or sediment effect on salinity tolerance was detected.

Chemical composition—The concentration of nitrogen in blade tissue, and to a lesser extent phosphorus, declined with increasing salinity. For nitrogen, this pattern conflicts with that reported by Twilley and Barko (1990), who found an increase in nitrogen concentration with increasing salinity. Water column concentrations in Twilley and Barko's experiment were very low (maximum 1.6 μmol/l) and did not vary with salinity. They interpreted the increase in blade nitrogen as an osmoregulatory response. Our water column concentrations were substantially higher and mean concentrations declined with salinity ($r = -0.932$ and -0.907 for dry and wet seasons respectively, $n = 10$ and $p < 0.001$ in each case). Thus, the decrease in blade tissue nitrogen with increasing salinity ($r = -0.872$ and -0.985, $n = 10$ and $p < 0.01$ in each case) may have been a response to decreasing water column concentrations. Kemp and co-workers (1984) reported a similar effect in *Potamogeton perfoliatus.* Blade nitrogen increased in response to increasing nutrient loading.

The decline in the concentration of chlorophyll *a* in blades with increasing salinity suggests that plants growing at high salinity have a reduced capacity to harvest light for photosynthesis. This may in part explain the progressively slower growth as salinity increased and the negative correlation between net oxygen production and salinity that we observed. Twilley and Barko (1990) detected no effect of salinity on concentration of chlorophyll *a* or on growth of plants.

Effects of site on the growth, chemical composition, and survival of *V. americana* have been observed previously. Although the possible reasons for such differences are many, they have often been attributed to contrasting sediment types (Titus and Stephens, 1983; Rybicki and Carter, 1986; Rogers et al., 1995). Although we found no difference in the ability of sediments from two sites in the Caloosahatchee to support growth of *V. americana,* sediment significantly influenced the concentration of P in blades. *V. americana* obtains the majority of its P from the sediments (Carignan and Kalff, 1980), and the compositional difference that we observed perhaps reflected a difference in the mobility or concentration of P in the two sediment types.

CONCLUSIONS—Our results indicate that salinity is an important factor regulating the growth of *V. americana* in the Caloosahatchee Estuary. *V. americana* survived salinities up to 15‰, a value higher than previously reported in the literature. Net growth ceased or was very slow at 15‰ and this salinity is at or near the upper tolerance limit for growth of *V. americana* in the Caloosahatchee.

We found no evidence that position in the estuary or differences in exposure to salinity caused by seasonal variation in freshwater discharge affected salinity tolerance. From a management perspective, the results suggest that the determination of a freshwater discharge commensurate with a suitable salinity for growth of *V. americana* in the upper Caloosahatchee need not account for a seasonally or spatially varying salinity tolerance. The growth response to increasing salinity did vary seasonally, with a threshold response in the winter and a monotonic decrease in the summer. This seasonal difference in pattern may be due to seasonal differences in growth rate. Since growth was slower in winter, the monotonic response we observed in summer may not have had sufficient time to develop in a 6 week winter experiment.

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FOOD HABITS OF THE LOWER FLORIDA KEYS MARSH RABBIT (*SYLVILAGUS PALUSTRIS HEFNERI*)

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Abstract: *Fecal pellets from 40 Lower Keys marsh rabbits (*Sylvilagus palustris hefneri*) were analyzed to determine the food habits of this endangered subspecies. Two grass species (*Sporobolus virginicus *and* Spartina spartinae*), one succulent shrub (*Borrichia frutescens*), and one tree species (*Laguncularia racemosa*) made up over 70% of diets. With some exceptions,* S. p. hefneri *fed on the plant species that are most abundant in its habitat. Unlike other rabbits and hares, the major components of Lower Keys marsh rabbit's diet did not significantly vary between seasons, sexes, and sites.*

Sylvilagus *palustris hefneri,* the Lower Keys marsh rabbit, is a recently listed endangered subspecies (U.S. Fish and Wildlife Service, 1990). Historically, the range of this subspecies extended from the southernmost of the Florida Keys, Key West to Big Pine Key. Habitat destruction, fragmentation, and other human disturbances have limited the subspecies to three of the Lower Keys.

Lower Keys marsh rabbits inhabit the transition zone, an area of high marshes and grasslands that lies between mangroves and upland hardwood hammocks. Both salt and fresh water marsh plants occur in this zone, along with bunch grasses, shrubs, and small trees. Primarily due to habitat destruction, the transition zone exists as a highly fragmented mosaic of native and disturbed patches, with few contiguous areas >5 ha (Forys and Humphrey 1996).

The only information on the food habitats of *S. palustris* is from a study of the mainland subspecies (*S. p. paludicola*). Blair (1936) found that caged marsh rabbits ate over 35 species of grasses and forbs, and the leaves or twigs from 18 tree species. Although this study showed the large variety of plants marsh rabbits are capable of eating, it did not investigate which plants marsh rabbits ate in the wild. Knowledge of Lower Keys marsh rabbit diet is vital to the subspecies' management, both for habitat preservation and restoration.

The objective of this study was to evaluate the food habits of the Lower Keys marsh rabbit and to determine if these habits vary between sexes and seasons.

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METHODS—I conducted this study on Navy owned land on Boca Chica Key (81°41′N, 24°34′W) and Saddlebunch Key (81°34′N, 24°37′W). I used five patches of occupied marsh rabbit habitat: four on Boca Chica and one on Saddlebunch. A patch was defined as an area of transition zone habitat that was isolated from another patch by a major road or large body of water. Detailed data on the movements of *S. p. hefneri* show that individual marsh rabbits spend most of their lives in one patch but can move to other patches. Marsh rabbits are born in a patch of transition-zone habitat and remain there until they reach sexual maturity. At sexual maturity most rabbits make a relatively long, one-way movement (Forys and Humphrey 1996).

Trapping occurred twice during the wet season (June–November), and twice during the dry season (December–May) for two years. I set Tomahawk brand mesh collapsible traps without bait, and sexed, weighed, and ear tagged (Monel no. 3, National Band and Tag, Newport, KY) all rabbits caught. A pan below each trap collected fecal pellets, and 10 of these pellets constituted a sample. To avoid experimental bias, pellets were collected only from adult animals one time. At each site, I collected pellet samples from eight rabbits, two of each sex during both seasons totaling 40 pellet group samples.

Fecal pellets were dried and crumbled to prepare microscope slides following standard procedures (Johnson et al., 1983). One hundred microscope fields (20/slide) were examined for each sample. Plant species were identified by comparing epidermal structures from the samples with a reference collection of plant tissues collected at the trapping sites. Average relative densities were calculated for each food item.

These relative densities may not be directly comparable to the amount of each type of vegetation ingested, as variation in the digestion and retention rate of different plant species can bias the results (Wallage-Drees et al., 1986; Westoby et al., 1976; Batzli and Pitelka, 1971). These biases can be quantified by comparison of fecal and stomach samples, but this is impractical in many studies (Johnson and Pearson, 1981), especially those involving endangered species.

To avoid these problems and still obtain data on the differences between available vegetation and vegetation in the rabbit's diet, I compared the species available and the species used. Available vegetation (ground cover) at the five sites was estimated using the line intercept method (Canfield, 1941). Ten 5-m-long transects were randomly located and the percent occlusion by each plant species on the transect was measured.

The relative densities are comparable between samples, because the digestion and retention rates are fairly constant for each plant species (Wallage-Drees et al., 1986). Univariate analyses of variance (PROC GLM—SAS Institute, Inc., 1988) were performed on arcsine-transformed estimates of dietary composition (%) for the most abundant species in the samples. Data from the two years were pooled to provide sufficient sample sizes to examine the differences between pellet groups from different sites, seasons, and sexes.

RESULTS—Nineteen plant species representing 14 families were found in the fecal pellets of 40 rabbits (Table 1). Two grasses, *Sporobolus virginicus* and *Spartina spartinae,* comprised over 50% of all diets. Two mangrove species, *Laguncularia racemosa* and *Rhizophora mangle,* and a small succulent shrub *Borrichia frutescens,* made up another 25%. The remainder of the species were grasses, sedges, shrubs and trees.

Three species, *Monanthochloe littoralis, Conocarpus erecta* and *Pithecellobium guadelupense,* were abundant at the transition zone sites, but were absent from the marsh rabbit's diet (Table 1). Key grass (*M. littoralis*) is a short wiry grass, and buttonwood (*C. erecta*) and blackbead (*P. guadelupense*) are tree species. Excluding these species, marsh rabbits generally fed on the most abundant species available. A Pearson's correlation between the average relative density of each plant species in fecal pellet group samples

TABLE 1. Mean (± SE) relative density of each plant species in fecal pellet group samples (N = 40) of *Sylvilagus palustris hefneri* and the mean (± SE) ground cover for the 19 most abundant species measured in 5 transition zone habitat patches in the Lower Keys of Florida.

Plant species	Mean relative density of plant species in fecal pellets	Mean ground cover
Sporobolus virginicus—Poaceae	35.74 (5.21)	14.60 (4.31)
Spartina spartinae—Poaceae	17.33 (3.87)	17.40 (8.49)
Laguncularia racemosa—Combretaceae	10.25 (2.49)	1.20 (0.20)
Borrichia frutescens—Asteraceae	8.40 (1.51)	8.40 (3.80)
Rhizophora mangle—Rhizophoraceae	6.81 (1.97)	1.00 (0.32)
Andropogon glomeratus—Poaceae	6.14 (2.04)	4.20 (2.01)
Eleocharis cellulosa—Cyperaceae	3.75 (1.63)	0.80 (0.49)
Typha latifolia—Typhaceae	2.10 (0.77)	1.00 (1.00)
Unidentified material	1.64 (0.50)	0.00
Muhlenbergia filipes—Poaceae	2.27 (1.32)	2.60 (1.19)
Coccoloba uvifera—Polygonacea	1.35 (0.81)	1.00 (0.63)
Sesuvium maritimum—Aizoaceae	0.63 (0.10)	0.80 (0.80)
Jacquinia keyensis—Theophrastueae	0.75 (0.30)	0.05 (0.01)
Fimbristylis castanea—Cyperaceae	0.76 (0.38)	4.20 (1.91)
Salicornia virginica—Cheropodiaceae	0.63 (0.31)	1.40 (0.93)
Avicennia germinans—Avicennianceae	0.38 (0.23)	1.00 (0.32)
Baccharis halimifolia—Asteraceae	0.31 (0.18)	0.10 (0.04)
Erithalis fruticosa—Rubiaceae	0.24 (0.17)	0.20 (0.12)
Fimbristylis spathacea—Cyperaceae	0.23 (0.23)	1.60 (1.17)
Maytenus phyllanthoides—Celastraceae	0.17 (0.17)	0.15 (0.10)
Conocarpus erecta—Combretaceae	0.00	2.80 (0.74)
Monanthochloe littoralis—Poaceae	0.00	4.40 (1.94)
Pithecellobium guadelupense—Fabaceae	0.00	2.00 (2.00)

and the average ground cover at the trapping sites was highly significant ($r^2 = 0.80$, $P < 0.001$, $n = 40$).

The four most abundant species in the marsh rabbit's fecal pellets, *S. virginicus*,. *S. spartinae, B. frutescens,* and *L. racemosa,* were used in the univariate analysis. Univariate analysis indicated a significant between season difference in the relative density of *S. spartinae,* and a significant season by sex interaction in *S. virginicus,* and *S. spartinae* (Table 2). There were no significant differences found among sites or between sexes for any of the plant species.

DISCUSSION—With some exceptions, *S. p. hefneri* appears to feed on the plant species that are most abundant in its habitat. The major plant species in the rabbit's diet did not vary statistically among sites, between wet and dry seasons (with one exception), or between males and females. These results differ from the majority of leporid dietary studies.

Few studies have investigated the effect of site on diet. Wallage-Drees and co-workers (1986) found that site did significantly affect the diets of *Oryctolagus cuniculus,* however, these sites differed greatly in vegetative

TABLE 2. Results of univariate analysis of variance on arcsine-transformed percentage relative density of *Sporobolus virginicus* (Sv), *Spartina spartinae* (Sp), *Laguncularia racemosa* (Lr) and *Borrichia frutescens* (Bf) in the fecal pellets of *S. p. hefneri* in the Lower Keys of Florida (* $0.05 \geq P > 0.01$; ** $0.01 \geq P > 0.001$; ns = $P > 0.05$).

		Sv		*Sp*		*Lr*		*Bf*	
Source	df	F	P	F	P	F	P	F	P
Site	5	0.87	ns	1.38	ns	1.15	ns	0.97	ns
Season	1	2.39	ns	11.61	**	2.27	ns	1.26	ns
Sex	1	0.21	ns	1.26	ns	0.04	ns	0.01	ns
Season by sex	1	15.71	**	6.24	*	2.19	ns	0.00	ns

composition. A portion of the sites were in woodlands, while others were in heathlands and abandoned arable fields. In contrast, *S. p. hefneri* is very specialized in its habitat use. It mainly uses transition zone habitat that has abundant clump grasses (*Spartina spartinae, Fimbrystylis* sp.) and little canopy cover (Forys and Humphrey 1999). It appears the lack of a significant difference among *S. p. hefneri*'s diet at the five sites may be related to this habitat specificity and it is possible that the dietary requirements of *S. p. hefneri* contribute to its habitat specificity.

Seasonal changes in leporid diets have been extensively documented (Cervantes and Martinez, 1992; Chapman et al., 1982; Dunn et al., 1982). In most of these studies, the climate and vegetation changed extensively between seasons. In the Keys, these changes may be more subtle. Although the Florida Keys lie a few degrees north of the Tropic of Cancer, the climate can be considered tropical (Walter, 1985). The temperature in the Lower Keys has never fallen below freezing. Rainfall is seasonal, but the Keys do receive ⅓ of their rainfall during the "dry" season. The percentage and composition of ground cover do not change significantly between seasons (Forys, 1995), although most growth does occur after the onset of the wet season. The significant seasonal effect in the proportion of *S. spartinae* in the rabbit's diet is probably due to the advent of new growth during the wet season.

No studies comparing male and female diets were found in the leporid literature, although McCreedy and Weeks (1993) found that male and reproductive female cottontails (*Sylvilagus floridanus*) differ in their nutrient requirements. *Sylvilagus p. hefneri* breeds year-round, with an equal number of litters during the wet and dry seasons (Forys, 1995). Although no significant dietary differences were found between sexes, the significant interaction between season and sex, *S. virginicus* and *S. spartinae,* may reflect additional nutritional requirements of pregnancy during different seasons.

In conclusion, *S. p. hefneri* feeds on a variety of the plant species found in its habitat, with some minor seasonal variation. Because no data on specific nutritional requirements are available, attempts at habitat maintenance or restoration should involve emulating the vegetative composition characteristic of occupied marsh rabbit habitat.

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PREDATION BY THE BLACK IGUANA (*CTENOSAURA SIMILIS*) ON THE PAINTED GHOST CRAB (*OCYPODE GAUDICHAUDII*) IN COSTA RICA

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ABSTRACT: *Although primarily a herbivore, there are a few observations of the terrestrial Central American black iguana eating bats, rodents, lizards and their eggs, frogs, chicks and other small birds, insects and spiders, as well as the eggs and juveniles of its own species. To this list of animal prey can be added an intertidal-dwelling crustacean, the painted ghost crab (*Ocypode gaudichaudii*), which this lizard has been observed to capture on a beach in Puntarenas Province, on the northwestern coast of Costa Rica.*

THE black iguana (*Ctenosaura similis*) is a large (to over 1 m total length) lizard distributed from Mexico to Panama where it is found in open woodland or edge habitat in seasonally dry lowlands (Fitch and Henderson, 1978). In Costa Rica, it co-occurs with no other member of the genus (Savage and Villa, 1986). Most species of lizards are primarily predators, and only about 2% are primarily herbivorous (Halliday and Adler, 1986). The black iguana is in this minority, based on analysis of dentition (Hotton, 1955) and on stomach contents (Fitch and Henderson, 1978). Fitch and Hackforth-Jones (1983) noted that in the rainy season when succulent vegetation is abundant the lizard is not highly selective and then crops low vegetation, and in the dry season when food is scarce, flowering and fruiting trees become important sources, and this lizard then often climbs trees. However, there are a few records of its food including terrestrial small mammals, lizards, including eggs and young of its own species, young birds, insects and spiders (Fitch and Henderson, 1978; Fitch and Hackforth-Jones, 1983). That this lizard feeds on any crustacean, especially on an open beach, has not been previously recorded.

The semiterrestrial crabs in the genus *Ocypode,* known as ghost crabs, racing crabs, sand crabs, and ocean sprites, occur circumglobally and mainly in the tropics (Trott, 1988). The painted ghost crab, *Ocypode gaudichaudii,* is a distinctive crimson red and is mostly day-active on intertidal sand beaches from El Salvador to Chile and the Galapagos Islands (Trott, 1988; Schober and Christy, 1993). Both sexes dig burrows to help avoid predators, environmental extremes, and conspecifics, and in which they stay when covered by the tide (Schober and Christy, 1993). Trott (1987) noted crab burrow densities in a 10 m sq. quadrat of up to 200, and the majority of burrows were from the mean high tide mark to 20 m below it. Food is typically organic matter associated with sand (“deposit feeding”), and live and dead matter of plant and animal origin (Trott, 1988).

OBSERVATIONS AND DISCUSSION—Observations were made on a beach on 17–18 March 1998 at Refugio de Fauna Silvestre Curu/Curu Hacienda between Punta Quesara and Punta Curu, on the Pacific Ocean at the southern end of the Nicoya Peninsula, Puntarenas Province, northwestern Costa Rica. The gray-sand beach is 900 m long by 70 m wide and has a 3.5% slope. Immediately above the beach is a forest of coconut palm (*Cocos nucifera*) and a dense understory of coco plum (*Chrysobalanus icaco*) and much debris (shed coconut leaves, coconuts, and tide-deposited wood). The beach and adjacent was long part of a working ranch and, more recently, an ecotourist facility and a national wildlife refuge. The black iguana was common on the near-beach area, and the painted ghost crab was common on the beach.

On 17 March I observed a black iguana to make a rapid and deliberate rush of some 5 m and grasp an adult painted ghost crab in its jaws, smash it against the sand, crush it in its jaws, and then devour it. The attack was at 12:25 PM on a sunny clear day; the air temperature in the shade above the beach was 40.5 C, and the ground temperature there was 43 C. The tide was at near low. The lizard then moved off the beach into the adjacent vegetation. There was no other lizard on the beach.

By measuring the distance between pieces of wood on which this lizard rested, I determined its total length as 0.74 m. By comparing the size of three legs lost from the eaten crab with those of crabs I captured, I could determine that the maximum cephalothorax width of the eaten crab was 35 mm and its maximum width when standing, including the legs, was 72 mm. My efforts over the next 1½ days to observe additional such predation proved fruitless.

Earlier that day at about the same time and under similar weather and tide conditions I had observed several groups with dozens of crabs in each ranging over the lower-most beach and near the water. At the time of the attack, the crabs were in a large section of the upper-most approximately one-third of the beach, spaced out individually near their burrow openings, usually about 30–122 cm (mean about 1 m or less) apart.

I found this predation to be noteworthy, and the next day mentioned it to Mr. Luis Schutt, who, with his family and assistants, manage the current operations at Curu. I discovered that Mr. Schutt has lived for most of his 29 years where the observations were made and that he has a strong interest in natural history. Mr. Schutt then related that that day, and near the site and time of my observation, he saw an "about 2½ foot-long" black iguana hunt painted ghost crab 15 m down from the upper-most beach. He noted that all crab escaped by running into their burrows. About a week earlier he had seen two similar-sized black iguana on the beach, one about ¼ of the way to the water from the uppermost beach, and the other about ½ of the way, near mid-day and at "exactly low tide". Both lizards were parallel to each other and moved in the same direction. His presence disturbed them and they ran off, but he "felt sure" that they were hunting painted ghost crab.

Upon questioning, Mr. Schutt revealed that over several years he had observed "some 15–20" captures of the painted ghost crab by *Ctenosaura similis* there. He observed the black iguana to mostly pursue the crabs when they formed tight groups of between some 50 and 100 individuals and moved over the lower beach, where they were far from their burrows. Mr. Schutt said such crab are "easy" prey for they then cannot outrun the lizard. However, my observations indicate that the lizard can successfully capture crab even when they are near their burrows. Although several other species of crab occur locally, Mr. Schutt observed predation by the lizard only on the painted ghost crab.

My observations were made in mid-dry season, when food for the black iguana may have been scarce and the abundant painted ghost crab on the upper beach may have attracted the lizard. Janzen and Brodie (1995) report that the black iguana has a clear visual preference for biting at brightly-colored objects, especially yellow, red, and pink flowers, and similarly-colored plasticine replicas of brightly-colored snakes. This might explain why the crimson-red painted ghost crab, especially when in motion, may be especially noticeable to the lizard and why it is hunted, and why other species of local crabs apparently are not. However, because the painted ghost crab is restricted to only a small part of the Pacific Coast portion of the distribution of the black iguana, it can be potential prey to only a small proportion of the total population of the black iguana.

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MITIGATION OF HARMFUL ALGAL BLOOMS, AN ANNOTATED BIOLIOGRAPHY: 1986–1998

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ABSTRACT: *An annotated bibliography is given of studies published between 1986 and the 1st quarter of 1998 of possible methods to predict/monitor or manage harmful algal blooms. Prediction/monitor methods include satellite imaging and absorption signatures. Management methods include mechanical controls, predation, infection, and treatment by natural and synthetic chemicals.*

SINGLE-celled algae, called phytoplankton, are present throughout marine and fresh water systems. On some occasions they can become so numerous that they color the water, giving rise to a phenomenon known as red tides. If the bloom is toxic or dangerous it is classified as a harmful algal bloom (HAB). Among the issues facing the United States today, HABs are thought to be one of the more scientifically complex and socially relevant (Anderson and Garrison, 1997). HABs are not unique to the United States. Many countries worldwide have suffered adverse economical impacts due to commercial and recreational losses. In addition, HABs can cause severe health problems, such as amnesic shellfish poisoning, ciguatera poisoning, diarrhetic shellfish poisoning, neurotoxic shellfish poisoning, and paralytic shellfish poisoning. Symptoms range from mild neurological and gastrointestinal disorders to paralysis and death.

Some believe that there is an urgent need for predicting HABs (Honjo et al., 1991) to diminish their impact, while other groups concentrate their efforts on trying to find a way to manage HABs in small, confined areas, such as fish hatcheries and shrimp farms.

The coastal waters of Florida are often plagued by red tides of the dinoflagellate *Gymnodinium breve*. Management methods considered for this red tide have included both biological and chemical methods. Methods tried before the 1980s have been mentioned elsewhere (Rounsefell and Nelson,1966; Steidinger,1973, 1983; Martin and Martin, 1976; Taft and Martin,1986; Martin et al.,1988). Chemical methods included screening of 4306 compounds to determine which were lethal toward *G. breve* (Marvin and Proctor, 1964), and aerial dusting with copper sulfate, among others. Chemical methods also include flocculation with clays (Howell and Shelton, 1970; Yu et al., 1994a, b, c; Anderson, 1996), and treatment by allelopathy, i. e., chemicals produced by other organisms (Pütter, 1907a, 1907b; Maestrini and Bonin, 1981; Taft and Martin, 1986; Martin et al., 1988; Flynn and Martin, 1988; Pérez et al., 1997; Martin and Taft, 1998). Biological methods have included nutrient competition by marine bacteria (Hunter and McLaughlin, 1958) and predation by grazers *ciliate* (Martin et al., 1973) and *Tintinnideae* sp. (Kutt and Martin, 1975).

Harmful algal blooms are a growing global problem (Smayda, 1990; Anderson, 1995,1997). Direct control of marine blooms might help reduce this problem. Following is an annotated bibliography of methods that have been evaluated in the quest to predict/monitor and/or manage harmful algal blooms during 1986 to early 1998. The list is not exhaustive, although every effort was made to include representative studies during this time period.

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PREDICTION/MONITORING

Satellite Imaging

Celone, P. J., and R. J. Smith. 1992. Satellite imagery for environmental monitoring and management. Sea Technol. 33:19–23.

In 1987, a *Gymnodinium breve* red tide occurred off the North Carolina coast, causing $25 million in losses. This particular bloom originated in the Gulf of Mexico, off the west-coast of Florida, and was tracked during its trajectory toward North Carolina by the National Oceanic and Atmospheric Administration's (NOAA) polar-orbiting satellites. The satellites detected ocean thermal features and derived sea surface temperature data. In 1988, the National Marine Fisheries Service (NMFS) researchers were able to calculate speed and trajectory of the bloom by combining Gulf Steam velocity profiles and retrospective satellite data. Results agreed with what had actually occurred.

NOAA's Beaufort Laboratory runs the "Coastal Ocean Program" (COP). This program was established in 1990 to address critical coastal issues involving fisheries productivity, environmental quality, and coastal hazards. COP researchers are trying to integrate water quality monitoring with photodiode-array spectrophotometry/high pressure liquid chromatography-based indicators of phytoplankton species that bloom and tide- and wind-based hydrological modeling. Research is also underway to derive chlorophyll concentrations and primary productivity from quantitative ocean color measurements. The program intends to use satellite imagery for environmental monitoring and management red tides, among others.

Pelaez, J. 1987. Satellite images of a "red tide" episode off Southern California. Oceanol. Acta 10(4): 403–410.

A red tide caused by *Gymnodinium flavum* developed off La Jolla, California, in July 1980. Data from forty-three satellite overpasses were collected and analyzed at the Scripps Satellite-Oceanography Facility.

Results indicate that intense phytoplankton growth started at coastal upwelling centers. The very high pigment concentrations observed along a segment of the coast apparently resulted from a combination of *in situ* growth and transport of high-pigment by warm water into that coastal area by ocean circulation. This caused an unusually strong and persistent coastal upwelling episode. Onshore advection of warm water made nutrients suddenly unavailable to the dinoflagellate, dissipating the red tide. This demonstrates that satellite images have potential in forecasting of red tides.

Absorption Signature Studies

Millie, D. F., O. M. Schofield, G. J. Kirpatrick, G. Johnsen, P. A. Tester, and B. T. Vinyard. 1997. Detection of harmful algal blooms using photopigments and absorption signatures: a case study of the Florida red tide dinoflagellate, *Gymnodinium breve.* Limnol. Oceanogr. 42(5,2): 1240–1251.

This study evaluated the use of photopigments and absorption signatures to detect and enumerate the red tide dinoflagellate, *Gymnodinium breve.* The carotenoid gyroxanthin-diester was found to be an adequate biomarker. Stepwise discriminant analysis indicated that mean-normalized absorption spectra for laboratory cultures of *G. breve* could be differentiated from spectra for cultures of a diatom, a prasinophyte, and peridinin-containing dinoflagellates. The fourth-derivative analysis discerned absorption maxima of pigments within the overall absorption spectra that were not readily observable. Derivative spectra may provide an effective means of interpreting absorption spectra from unknown species mixtures. However, gyroxanthin-diester provides only a minor contribution to the cellular absorption and has absorption maxima similar to those of carotenoids and chlorophyll *c*. Consequently, it is not feasible to delineate this pigment through remote sensing at the present time. Using the similarity algorithm in conjunction with fourth-derivative analysis can minimize this difficulty.

Models

Franks, P. J. S. 1997. Model of harmful algal blooms. Limnol. Oceanogr. 42 (5): 1273–1282.

Models of harmful algal blooms (HABs) are a small subset of models used in biological oceanography or plankton ecology. Four models used to explore HABs were presented: aggregated models, multispecies models, models with simple physics and models with detailed physics. The author concludes that better physical and biological models need to be developed to allow better predictions of HABs.

Effects Of Physical/Chemical Characteristics

Honjo, T., M. Yamaguchi, O. Nakamura, S. Yamamoto, A. Ouchi, and K. Ohwada. 1991. A relationship between winter water temperature and the timing of summer *Gymnodinium nagasakiense* red tides in Gokasho Bay. Bull. Jap. Soc. Sci. Fish. 57(9): 1679–1682.

The dinoflagellate *Gymnodinium nagasakiense* causes noxious red tides in western Japan and southern Korea. This study focused on predicting *G. nagasakiense* red tides based on water temperatures. Results indicated a strong relationship between the timing of summer *G. nagasakiense* red tides and winter water temperature, implying that timing of these red tides was predictable several months before the summer. Prediction might allow enough time to implement plans that avoid damage.

Mitigation Techniques For Net Pen Aquaculture

Iwata, Y., I. Sugahara, T. Kimura, K. Silapajarn, M. Sano, T. Mizuguchi, A. Nishimura, M. Inoue, and T. Takeuchi. 1997. Growth potential of *Gymnodinium mikimotoi* in Gokasho Bay. Bull. Jap. Soc. Sci. Fish. 63(4): 578–584.

This study focuses on the algal growth potential (AGP) of *Gymnodinium mikimotoi* in the Gokasho Bay, Japan, during the period from 1991 to 1994. The high AGP of the seawater was monitored at several depths ranging from 0.5 to 1m above bottom. Results indicated the possibility of predicting red tide by AGP of seawater at a depth of 1.0 meter above the bottom. In addition, results suggest that phosphorus was the nutrient factor that controlled the development of this red tide organism.

Uchida, T., Y. Matsuyama, M. Yamaguchi, and T. Honjo. 1994. A monitoring of toxic phytoplankton in the counterplan of shellfish poisoning. Bull. Jap. Soc. Sci. Fish. 60(5): 685–688. (In Japanese.)

Non vidi.

MANAGEMENT/MITIGATION STUDIES

General

Anderson, D. M. 1996. Control and mitigation of red tides. December 4. Manuscript prepared for Project START (Solutions to Avoid Red Tide), Sarasota, FL. 59 pp.

The author provided a review of the biology of *G. breve* and formulated a research agenda which addressed many issues involved in the evaluation of various strategies to control and mitigate red tide blooms.

Direct control strategies include chemicals that kill or disrupt red tide cells; flocculating materials such as clays; lethal pathogens to red tide algae such as viruses, bacteria, and parasites.

The author did not recommend the investment of significant funds to search for chemical compounds until the receptivity of federal and state agencies and the general public are assessed toward this approach since widespread application of chemicals to the ocean is rare. One of the concerns of this approach includes the identification of a chemical that targets *G. breve* without affecting other algae and marine animals.

Flocculation with clays was presented as a promising technique because foreign workers have acquired data on this; clays are generally harmless to all marine organisms, including fishes; they are relatively inexpensive; and clay flocs provide food in the benthos.

Biological controls based on parasites, viruses and bacteria have potential but a great deal of preliminary work is needed in order to isolate the organisms, identify them, test for specificity among strains of *G. breve*, understand the dynamics of infection and replication, and determine the environmental impact of the release of the organisms.

Indirect controls, or prevention include reducing pollution to reduce nutrients; prediction of red tide outbreaks by development of models or remote sensing; and collection and removal of dead fish before they wash up on beaches to minimize the impact.

SHIROTA, A. 1989. Red tide problem and countermeasures (2). Int. J. Aq. Fish. Technol. 1:195–293.

Non vidi. Cited by Anderson (1996).

PREDATION STUDIES

JEONG, H. J., AND M. I. LATZ. 1994. Growth and grazing rates of the heterotrophic dinoflagellates *Protoperidinium* spp. on red tide dinoflagellates. Mar. Ecol. Prog. Ser. 106:173–185.

This is the first report on the growth and grazing rates, and prey selection, of *Protoperidinium* cf. *divergens* and *P. crassipes* feeding on dinoflagellate prey. Diets of the larger dinoflagellates *Gonyaulax polyedra* and *Gymnodinium sanguineum* supported population growth of *Protoperidinium*, but smaller dinoflagellates *Prorocentrum* cf. *balticum* and *Scrippsiella trochoidea* did not. Maximum specific growth rates and ingestion rates were determined. Results indicated that *Protoperidinium* grazing might be important in regulating the populations of some red tide dinoflagellates, especially during the peak and decline of red tides.

NAKAMURA, Y., Y. YAMAZAKI, AND J. HIROMI. 1992. Growth and grazing of a heterotrophic dinoflagellate, *Gyrodinium dominans*, feeding on a red tide flagellate, *Chattonella antiqua*. Mar. Ecol. Prog. Ser. 82: 275–279.

This study evaluated the grazing and growth of the dinoflagellate *Gyrodinium dominans* in laboratory cultures. *G. dominans* was found to ingest *Chattonella antiqua* at a rate of 3.8 prey cells^{-1} day^{-1}, and grow at a rate of 0.88 d^{-1} at 25 °C. Temperature affected the growth of *G. dominans*. A maximum growth occurred within the range 25 to $\geq$ 27 °C, and a minimum growth occurred around 20°C (minimum temperature evaluated in the study). *G. dominans* cell division remained the same throughout light and dark periods. In addition, the growth efficiency of *G. dominans*, based on C and N contents, was evaluated and found to be 0.31 and 0.33, respectively. Results suggest the ecological importance of *G. dominans* in the disappearance of *C. antiqua* red tides. The authors concluded that *G. dominans* has a potential ability to control the population of *C. antiqua*.

TAKEDA, S., AND Y. KURIHARA. 1994. Preliminary study of management of red tide water by the filter feeder *Mytilus edulis galloprovincialis*. Mar. Poll. Bull. 28(11): 662–667.

This study investigated whether the mussel, *Mytilus edulis galloprovincialis*, will prey on red tide plankton thus lessening mass mortality of fish affected by the red tide organism *P.*

luteri. In addition, the feeding and digestion rates of the mussel feces by a deposit-feeding sea cucumber *Stichpus japonicus* were studied. The retention rate or filtration rate of the mussels were found to be related exponentially to the shell length. The mathematical expression governing this relation was determined and the filtration rate was calculated. The mussels effectively retained food particles larger than about 4 μm. Results also indicate that plankton at high density were removed faster than plankton at low density. The authors conclude that if mussels attached to ropes were transported to red tide water masses containing plankton bigger than 4 μm, the plankton would be effectively managed. But this management method will only work to manage red tides caused by non-toxic plankton, since toxins produced by toxic plankton could kill the mussels, according to the authors.

Infection Studies

Bratbak, G., W. Wilson, and M. Heldal. 1996. Viral control of *Emiliania huxleyi* blooms? J. Mar. Syst. 9: 75–81.

A literature search regarding virus-like-particles (VLPs) in phytoplankton cells is presented. Most of this information is concerned with the morphology, structure and size of the VLPs, their location in cells and tissue, and their effect on cell ultrastructure.

The article describes viral infection during blooms of *E. huxleyi* that occurred in the North Sea and suggests that the VLPs accumulated at the expense of the growing host cell population, preventing an *E. huxleyi* bloom from developing.

A plaque assay for viruses was developed. This allowed for the isolation and propagation of a virus that infects *E. huxleyi*. The virus was incubated with *E. huxleyi* and lysed the culture completely after 4–7 days. After examining the cultures through epifluorescence microscopy, the authors concluded that the virus was a double stranded DNA type. Subsequent re-infections required longer time for the *E. huxleyi* cultures to lyse, and after 6–10 re-infection cycles, the *E. huxleyi* virus became ineffective due to defective interfering particles produced by the alga.

Cottrell, M. T., and C. A. Suttle. 1995. Dynamics of a lytic virus infecting the photosynthetic marine picoflagellate *Micromonas pusilla*. Limnol. Oceanogr. 40(4): 730–739.

Micromonas pusilla viruses (MpV) are a group of lytic, double-stranded DNA viruses specific for the marine photosynthetic picoflagellate *Micromonas pusilla* (Prasinophyceae). The impact of MpVs on this picoflagellate were inferred from several studies, including the measurement of the abundance of MpV, kinetics of MpV adsorption to host cells, and the estimated in situ decay rate of MpV infectivity.

The viral infection rate, expressed as the number of host cells lysed per milliliter per day, was found to be depth-dependent, with an attenuation coefficient estimated to equal $0.73 m^{-1}$. Decay rates of MpV infectivity in seawater incubated in the dark ranged from $0.06 d^{-1}$ at 4 °C to $0.09\ d^{-1}$ at 25 °C. The adsorption coefficient for MpV and *M. pusilla* was 1.40×10^{-9} mL min^{-1}.

Results from this study demonstrate that viruses can be a significant source of mortality for populations of eucaryotic phytoplankton.

Furuki, M., and M. Kobayashi. 1991. Interaction between *Chattonella* and bacteria and prevention of this red tide. Mar. Pollut. Bull. 23:189–193.

Chattonella antigua is the causative organism of red tides in the Sea of Harima, Japan. This alga tends to cause red tides yearly and large scale red tides every 5 years. The relation between this fluctuation and communities and characteristics of bacteria was studied.

The study consisted of inoculating *C. antigua* in three different media, which consisted of sea water obtained from the Sea of Harima, enriched with nutrients. The media used were: SW1—sterilized sea water (filtered through 0.2 μm filter), SW2—plankton-free sea water (filtered through 1.2 μm filter), and SW3—raw sea water. Two tests were performed:

Test 1: Sea water withdrawn during the development of a bloom (*Chattonella* was growing in the sea): in SW1, proliferation of *C. antigua* did not show regular trend (no further details were given); in SW2, bacteria and *C. antigua* grew well; in SW3, *C. antigua* predominated over other aboriginal species of phytoplankton in interspecific competition and proliferated preferentially.

Test 2: Sea water withdrawn during the decline of a bloom: in SW1, proliferation of *C. antigua* did not show regular trend; in SW2, *C. antigua* was not able to proliferate but bacteria did; in SW3, *C. antigua* was not able to proliferate.

The bacteria present in SW2 and SW3 from both tests were isolated. Two bacteria were discovered, one that enhanced the growth of *Chattonella* and one that inhibited the growth of *Chattonella*. The former proliferated together with *Chattonella*. The latter was parasitic, using *Chattonella* as the nutrient for its proliferation. The authors concluded that the mechanism by which the bacteria controlled *Chattonella* could be utilized for the prevention of this red tide.

JACOBSEN, A., G. BRATBAK, AND M. HELDAL. 1996. Isolation and characterization of a virus infecting *Phaeocystis pouchetii* (prymnesiophyceae). J. Phycol. 32(6): 923–927.

Phaeocystis pouchetii (Hariot) Lagerheim is the causative organism of red tides off the Norwegian coast. A virus specific to *P. pouchetii* was isolated from a bloom of this alga in May 1995. The virus did not lyse 10 strains tested, only *P. pouchetii*. The latent period of the virus when propagated in cultures of *P. pouchetii* was 12–18 h, and the time required for complete lysis of the cultures was about 48 h. The burst size was estimated to be 350–600 viral particles per lysed cell.

MILLIGAN, K. L. D., AND E. M. COSPER. 1994. Isolation of virus capable of lysing the brown tide microalga, *Aureococcus anophagefferens*. Science, 266: 805–807.

The first documented brown tide blooms occurred in 1985, almost simultaneously, in Narragansett Bay, Rhode Island, Barnegat Bay, New Jersey, and Peconic Bay, Long Island. The blooms devastated populations of bay scallop and blue mussel resulting in severe monetary losses. Brown blooms have reappeared several times since. The causative organism has been identified as the alga *Aureococcus anophagefferens* (Chrysophyceae).

Virus-like particles (VLPs) were discovered in the original 1985 *A. anophagefferens* cells. The authors isolated the viruses by means of ultrafiltration. The lower filtration cutoff was 10,000 daltons.

Cultures of *A. anophagefferens* was bioassayed against the ultrafiltrate. Treatments consisted of additions of various volumes of the filtrate to test tubes containing 6 mL of *A. anophagefferens* (4.5×10^5 cells per mL). Growth of the alga was monitored as *in vivo* fluorescence yield of cell chlorophyll *a*. A virus infection was suspected when fluorescence decreased. Microscopic observations of infected cultures revealed only cellular debris and the absence of intact cells, indicating lysing of the cells. Samples from lysed cultures were filter-sterilized and inoculated into fresh cultures of *A. anophagefferens*, and monitored for growth. Serial transfers of lysate were also performed. Results showed that continuous reinfection occurred. Electron microscope surveys yielded images of phage-like virus particles with tails that could attach to *A. anophagefferens* cell within minutes of exposure. The authors conclude that viral infection has the potential to control algal blooms.

NAGASAKI, K., A. UCHIDA, AND Y. ISHIDA. 1991. A monoclonal antibody which recognizes the cell surface of red tide alga *Gymnodinium nagasakiense*. Bull. Jap. Soc. Sci. Fish. 57(6): 1211–1214.

Gymnodinium nagasakiense has caused red tides in Omura Bay, Nagasaki, Kumano-Nada, and Seto Inland Sea, among other places. When first discovered in 1965, it was tentatively called *Gymnodinium* Type-'65. After detailed observation and comparison of morphological features, it was named *Gymnodinium nagasakiense*. However, in clonal culture the cell shape variability was relatively large. Therefore, interspecies identification of genus *Gymnodinium* by morphological features was very difficult and unreliable. In order to clarify the grouping of these species, more objective criteria for identification are necessary.

A monoclonal antibody GN-89 that recognizes the cell surface of *Gymnodinium nagasakiense* was used. It was obtained from hybridoma which had been established by cell fusion between myeloma and spleen cell of a mouse immunized with the cells of a particular strain of *Gymnodinium nagasakiense*. GN-89 was reactive with nine strains of *Gymnodinium na-*

gasakiense Type-`65 and one strain of *Gyrodinium* sp., but not with *Gymnodinium breve, Gymnodinium caternatum, Gymnodinium* cf. *nagasakiense* (European species), and other genera of red tide algae.

The antigen recognized by GN-89 seemed to be very hydrophobic, because GN-89 reacted with the antigen, which was dissolved with diethyl ether but not with distilled water. The antigen had a polypeptide moiety, and the antigenic determinant was very heat-stable.

NAGASAKI, K., M. ANDO, I. IMAI, S. ITAKURA, AND Y. ISHIDA. 1994. Virus-like particles in *Heterosigma akashiwo* (Raphidophyceae): a possible red tide disintegration mechanism. Mar. Biol. 119: 307–312.

Viruses or virus-like particles (VPLs) were found inside and around the nuclear area of the alga *Heterosigma akashiwo* collected in 1992 in the middle or final stages of a red tide in Hiroshima Bay, Japan. *H. akashiwo,* (class Raphidophyceae) is an alga that causes red tide. When in bloom, it causes mortality of cultured fish such as salmon, yellowtail, sea bass, black sea bream and righteyed flounder in the coastal seas of the temperate and subarctic areas.

Surface water collected during a bloom of *H. akashiwo* in Japan in 1992 contained approximately 20,000 cells mL^{-1} of *H. akashiwo.* Eight days later, the collected water contained 66 cells mL^{-1} of *H. akashiwo* and 6400 cells mL^{-1} of *Prorocentrum triestinum.* A definite viral increase during host decrease was demonstrated, suggesting that viral lysis could account for more than 25% of net mortality.

The authors explored the dynamics of viruses in algal blooms by observing *H. akashiwo* cultures through an electron microscope. A typical *H. akashiwo* cell contains large pyrenoids and genophores in the chloroplasts, and osmiophilic fatty particles. It also has a nucleus. Cells harboring VPLs (5% of the population sampled) lacked an intact nucleus, Golgi apparatus and endoplasmic reticulum, suggesting that these cells were dying. The other organelles, chloroplasts, mitochondria and fatty particles remained intact.

Based on the morphology of the VLPs, they may belong to the Iridovirus or Phycodnavirus family, but further biological and chemical characterization is needed prior to proper identification.

Two possible sources of the VLPs are mentioned. One is that they derived from infectious lytic viruses, and the other is that they derived from lysogenic viruses in algal genome. Some change in the ambient conditions of the host alga may be an initiation trigger for the lysogenic virus causing viral replication in the algal cells, or some kind of mutation may occur during a vigorous multiplication in the bloom to change the temperate virus into an activated lysogenic virus.

Either of these hypotheses successfully explains the termination of the algal blooms.

NAGASAKI, K., M. ANDO, S. ITAKURA, I. IMAI, AND Y. ISHIDA. 1994. Viral mortality in the final stage of *Heterosigma akashiwo* (Raphidophyceae) red tide. J. Plankton Res. 16(11): 1595–1599.

This article is a continuation of the study reported above (Nagasaki et al., 1994); here the authors describe the possible involvement of viral lysis in the final stage of the *H. akashiwo* red tide.

Surface water was collected during a bloom of *H. akashiwo* in Hiroshima Bay, the Seto Inland Sea, Japan, during the second quarter of 1993. The cells were concentrated by centrifugation (2500 rpm × 20 min) and analyzed by transmission electron microscopy. Surface water collected during the decline of the bloom was incubated for 26 hr at 22°C and prepared for electron microscopy to detect viral replication. The proportion of *H. akashiwo* cells containing virus-like particles (VLPs) was monitored for each sample. Over 100 cells were observed for each sample. Until 3 days before the termination of the red tide, no VLP-containing cells were detected, and the proportion of VLP-containing cells was $< 1\%$ on the last 2 days of the red tide. The sample collected on the last day of the red tide had 11.5% of VLP-containing cells. Evidently viral mortality occurs in quite a short time and may play an important role in regulating the disintegration of *H. akashiwo* red tide.

CHEMICALS

Flynn, M. C., and D. F Martin. 1988. Inhibition of growth of a red tide organism, *Ptychodiscus brevis,* by a green alga, *Nannochloris oculata.* Microbios Lett. 39, 13–18.

The potential for inhibition of the unarmored dinoflagellate, *P. brevis,* responsible for Florida red tides, with a green-alga, *Nannochloris oculata,* was investigated. Two types of experiments were performed. One consisted of checking *P. brevis* (a.k.a. *Gymnodinium breve*) cells for inhibition of growth against *N. oculata* cells. The other type consisted of determining inhibition of growth of the *P. brevis* in cell-free *N. oculata* culture.

Results of the first experiment indicated that this species inhibited the growth of P. *brevis,* and the inhibition depended on the number of *N. oculata* cells present in the bioassay. When the initial ratio of *N. oculata* to *P. brevis* cells was about 2×10^{-2}, the growth of *P. brevis* was reduced to 50% of the control. *P. brevis* was reduced even more as the initial values of *N. oculata* were increased.

Results of the second set of experiments suggested that the inhibition was caused by allelopathy because growth of *P. brevis* was inhibited in the presence of cell-free cultures of *N. oculata.*

Ichikawa, S., Y. Wakao, and Y. Fukuyo. 1992. Extermination efficacy of hydrogen peroxide against cysts of red tide and toxic dinoflagellates, and its adaptability to ballast water of cargo ships. Bull. Jap. Soc. Sci. Fish. 58(12): 2229–2233.

Red tides are expanded throughout the world by transportation of cysts in the ballast water of cargo ships. Hydrogen peroxide was investigated as an exterminating agent against red tide cysts. The cysts were isolated when the cargo ship was washed. They were exposed to concentrations of hydrogen peroxide solutions ranging from 0–1000 ppm (0–0.1%) and incubated in sterile seawater. The germination ability of the cysts was evaluated.

Three types of red tide organisms were studied: *Polykrikos schwartzii, Alexandrium catenella* and *A. tamarense.* All were adversely affected by hydrogen peroxide. The cysts of *Polykrikos schwartzii* were exterminated after exposure to 100 ppm hydrogen peroxide for 24 h. No germination was observed from cysts of *A. catenella,* which were exposed to 30 ppm for 48 h. All cysts of *A. tamarense* showed protoplasm contraction and discoloration after exposure to 30 ppm hydrogen peroxide for 48 h. Hydrogen peroxide (100 ppm) in seawater broke down within 30 days. Results indicate that hydrogen peroxide is a potential exterminating agent against dinoflagellate cysts.

Kajiwara, T., S. Ochi, K. Kodama, K. Matsui, A. Hatanaka, T. Fujimura, and T. Ikeda. 1992. Cell-destroying sesquiterpenoid from red tide of *Gymnodinium nagasakiense.* Phytochemistry 31(3): 783–785.

The volatile compounds excreted by *Gymnodinium nagasakiense* into the medium were analyzed by GC/MS. The compounds were identified as sesquiterpene alcohols such as epicubenol, α-cadinol and cubenol. This is the first report of these compounds in phytoplankton. Cubenol was shown to increase in amount from the logarithmic phase to the stationary phase during culture of *G. nagasakiense,* and was shown to cause cell burst of swimming plankton such as *G. nagasakiense, H. akashiwo, Chatonella marina* and *C. antiqua* at 5 ppm.

Kawano, I., T. Oda, A. Ishimatsu, and T. Muramatsu. 1996. Inhibitory effect of the iron chelator Desferrioxamine (Desferal) on the generation of activated oxygen species by *Chattonella marina.* Mar. Biol. 126(4): 765–771.

Chattonella marina (Raphidophyceae) causes red tides in Japan. This phytoplankton is highly toxic to fish. It has been suggested that *C.* induces excessive secretion of gill mucus resulting in the blockage of respiratory water flow through the gill, interfering with O_2 transfer (Yamaguchi et al. 1981; Endo et al. 1985). This phytoplankton also produces activated oxygen species such as superoxide anion (O_2^-), hydrogen peroxide (H_2O_2), and hydroxyl radicals ($\cdot OH$), which may be responsible for its toxicity.

In this study, the authors investigated the involvement of iron in the generation of O_2^- and H_2O_2 by *C. marina.* The alga was inoculated into Erd-Schreiber modified medium (control) and iron-deficient medium (test), at initial cell-concentration of 1100–1300 cells mL^{-1}.

Growth was measured by counting living cells until growth reached a plateau. Results demonstrated the production of O_2^- in the test was low throughout the exponential growth phase and the stationary phase in comparison with controls. In addition, the growth rate of *C. marina* in the test was affected by the iron deficiency from Day 4 on. The authors attribute this delay of growth inhibition to the presence of trace amounts of iron in the natural seawater used.

The effect of a specific iron chelator, desferrioxamine (Desferal), on the generation of O_2^- and H_2O_2 by *C. marina* was also evaluated. Various concentrations of Desferal were added to a cell suspension (2.5×10^4 cells mL^{-1}) of *C. marina* and immediately assayed for O_2^- and H_2O_2. Results demonstrated that this chelator strongly inhibited the generation of both O_2^- and H_2O_2 in a concentration-dependent manner and inhibited the growth of *C. marina* at concentrations as low as 5μM. These results suggest that iron is required for the generation of activated oxygen species by *C. marina,* as well as for its own growth.

Martin, D. F. and W. H. Taft. 1998. Management of the Florida red tide—revisited. Florida Scient. 61(1): 10–16.

The authors reviewed control and mitigation criteria for Florida's red tide organism, *Gymnodinium breve,* with focus on ten criteria previously presented (Taft and Martin, 1986), misunderstandings were addressed and alternative points of view were presented. Three potential control agents that produce chemicals cytolytic toward *G. breve* (chemicals called APONIN, acronym for **AP**parent **O**ceanic **N**aturally occurring cytol**IN**) were reviewed. *Gomphosphaeria aponina* produced APONIN-1, *Nannochloris* sp. produced APONIN-2 and ψ-APONIN, which induced resting stage in *G. breve,* and *Nannochloris oculata* produced APONIN-3a and -3b.

Merriman-Clarke, K. 1997. Fisheries News: Ozone may rid shellfish of "red tide" toxins. Fisheries, 22(3): 49.

A simple, yet effective technique is being evaluated by Florida Sea Grant researchers, Gary Rodrick and colleagues, for the elimination of red-tide toxins from shellfish. These researchers claim that ozone can have a sterilizing effect on the shellfish and can chemically break apart red-tide toxins in addition to "extend the shelf life and improve their taste".

FDA has not yet approved the process in the U.S., but the method is common in Australia and France.

Mountfort, D. O., M. Atkinson, K. Ponikla, B. Burke, and K. Todd. 1996. Lysis of *Gymnodinium* species by the fungus *Verticillium lecanii.* Bot. Mar. 39(2): 159–165.

This study describes the effect of microorganisms isolated from a declining bloom on the growth of several dinoflagellates and attributes the effects to one marine microorganism. A total of 9 microorganisms (bacteria and fungi) were isolated from a phytoplankton bloom caused by *Gymnodinium* sp., which occurred in 1993 on the northeastern coast of New Zealand. Of the nine microorganisms, only two were prevalent during the decline of the bloom. These were identified as a marine bacterium designated str LY and the marine fungus, *Verticillium lecanii.* Pure cultures of these two organisms were bioassayed against the following dinoflagellates: *Gymnodinium mikimotoi* Miyake, *G. saguineum* Hirasaka, *Amphidinium carterae* Hulburt, *Alexandrium ostenfeldii* Balech, *A. minutum* Halim, *Gymnodinium* sp., and *Heterocapsa triquetra* Stein.

The bacterial strain LY did not affect any of these dinoflagellates. Though *V. lecanii* did not effect *Alexandrium ostenfeldii, A. minutum and Amphidinium carterae,* it slightly inhibited the growth of *Heterocapsa triquetra,* and it caused complete destruction of the three species of *Gymnodinium.* This fungus exhibited growth in the presence of *Gymnodinium* sp. At the end of the experiment the amount of fungus was $> 3 \times 10^3$ cells/mL compared with 5×10^2 cells/mL at the time of inoculation.

The authors theorized that *V. lecanii* released an agent into the culture fluid of the fungal-dinoflagellate co-cultures. This was tested by adding culture fluid from growth of *V. lecanii* on heat killed preparations of *Gymnodinium mikimotoi,* to growth cultures of three species of *Gymnodinium.* The effects were lysis of G. *mikimotoi, G.* sp. and *G. sanguineum.* The lytic agent was partially characterized by centrifuging the *V. lecanii* culture fluid in a microconcentrator with MW cutoffs of 3,000 and 10,000 daltons. Results indicated that the lytic system had a MW of < 3,000 daltons. Identification of the structure of the lytic system may allow for its direct addition to bloom affected waters, or through introduction of plasmids encoding for its production. The authors considered this latter approach more cost effective and feel that this will eventually provide a basis for the development of biocontrol methods in the management of phytoplankton blooms.

PÉREZ, E., W. G. SAWYERS, AND D. F. MARTIN. 1997. Identification of allelopathic substances produced by *Nannochloris oculata* that affect a red tide organism, *Gymnodinium breve.* Biomed. Lett. 56: 7–14.

The west coastal waters of Florida are frequently plagued with red tides produced by the unarmored dinoflagellate *Gymnodinium breve* Davis. *G. breve* has directly caused mass mortality of over 100 species of marine life (Steidinger and Ingle, 1972) by the production and release of neurotoxins.

The green alga *Nannochloris oculata* produces allelopathic substances toward *Gymnodinium breve.* The crude allelopathic substances, called APONIN-3 (**ap**parent **o**ceanographic **n**aturally occurring cytol**ins**), were obtained by extraction of cell-free cultures of *Nannochloris oculata* with chloroform, followed by partial purification with flash chromatography on silica gel. The allelopathic substances were analyzed by GC/MS and identified as methyl palmitate and methyl stearate. Results indicate that methyl palmitate and methyl stearate had negative effects on the survival of *G. breve* at concentrations of 5–2.5 ppm, and 5–3.5 ppm, respectively. Concentrations of either one below 1.9 ppm did not appear to affect the red tide organism. The authors conclude that the ability of *N. oculata* to produce allelopathic chemicals offers some potential for a natural control of *G. breve.*

TAFT, W. H., AND D. F. MARTIN. 1986. The potential for managing a Florida red tide. J. Environ. Sci. Health, A21(2):107–127.

The authors consider the potential for management of Florida red tide outbreaks, including approaches used in the past, such as extension of freshwater experience and massive testing of chemicals. The authors conclude that these two approaches were flawed, and believe that the solution should be sought in the marine environment, either with a natural product or by biocontrol. They found that chemicals produced by the alga *Nannochloris* sp., destroy the red tide organism *G. breve.* These chemicals were given the term APONIN, an acronym for **a**pparent **o**ceanic **n**aturally occurring cytol**in.** This same alga was also evaluated for biocontrol. This was performed by testing for toxicity using large-scale cultures. Bioassays were performed using various concentrations of *Nannochloris* sp. against *Cyprinodon variegatus* (sheepshead minnows), pre-reproductive *Mysidopsis bahia* (mysids), and juvenile *Neanthes arenaceodentata* (worms). No toxic effect was noted on any of these three organisms.

Advantages, uses and implications of a Florida red tide were discussed. Estimated costs of biocontrol were compared with the reported costs of a typical red tide outbreak on the west coast of Florida.

MECHANICAL CONTROL SYSTEMS

GIBSON, C. H., AND W. H. THOMAS. 1995. Effects of turbulence intermittency on growth inhibition of a red tide dinoflagellate, *Gonyaulax polyedra* Stein. J. Geophys. Res. 100(C12): 24,841–24,846.

This paper evaluated the effect of intermittent turbidity on the growth of the red tide dinoflagellate *Gonyaulax polyedra* Stein using the device and conditions used by Thomas and Gibson (1990). Results indicated that the growth of the organism was more sensitive to the intermittency of turbulence than the strength of the turbulence near the continuous threshold measured. When the turbulence rate of strain of 9 rad s^{-1} was used for periods of only 2.5, 1.0 and 0.25 hours during a day, increasingly negative growth rates were observed. Other dinoflagellate species concentrations showed a similar pattern of negative correlation with wave height, the opposite response was observed for diatoms.

HERSHBERGER, P. K., J. E. RENSEL, A. L. MATTER, AND F. B. TAUB. 1997. Vertical distribution of the chloromonad flagellate *Heterosigma carterae* in columns: implications for bloom development. Can. J. Fish. Aquat. Sci. 54: 2228–2234.

Blooms of the Raphidophyceae *Heterosigma carterae* have caused fish mortalities in many places, including Japan, Singapore and New Zealand. Previous studies indicated the presence of vertical stratification of the water column, which is often induced by freshwater runoff. The authors of this study provided laboratory evidence for the attraction and concentration of *Heterosigma* in the region above a halocline. The organisms tended to concentrate in surface regions of lesser salinity water, and the concentrations of cells were maintained 24 h a day when a halocline was present. In addition, the authors presented evidence for a proposed bloom formation mechanism, in which the cells migrated to the surface, possibly in response to a slight salinity gradient, and disappeared from the surface when vertical stratification is lost due to mixing or turbulence. The results may lead to bloom mitigation techniques for net pen aquaculture.

KISHIMOTO, Y., K. HATAMOCHI, AND H. MAEDA. 1996. Effects of vertical water-mixing against fresh-water algal bloom. Bull. Jap. Soc. Sci. Fish. 62(1): 3–11.

Vertical mixing of water was evaluated as a means of preventing fresh-water red tides at the Tonoyama reservoir in the Kii Peninsula. An underwater mixer was used to prevent blooms by a dinoflagellate, *Peridinium bipes.* A mesocosm was created by enclosing water of the reservoir with waterproof vinyl sheet fences. Water conditions, such as water temperature and DO, were kept uniform throughout the mesocosm by the vertical water flow generated with the underwater mixer.

In the summer of 1993, the usual large freshwater algal bloom did not appear in the reservoir due to the unusually cold temperature, high rainfall and repeated large volume discharges. The experiment was conducted at low *P. bipes* cell densities (15.4, 12.9, 12.5 and 21.0 cells mL^{-1}). Comparison of the cell density in the mixing area with those in the control area and outside of the mesocosm indicated a suppressed reproduction rate, suggesting that vertical mixing interfered with the formation of fresh-water red tides.

THOMAS, H. W. AND C. H. GIBSON. 1990. Quantified small-scale turbulence inhibits a red tide dinoglagellate, *Gonyaulax polyedra* Stein. Deep-Sea Res. Pt. A Oceanogr. Res. Pap. 37(10): 1583–1593.

This paper mentions several studies that have noticed that red tides occur when there is low turbulence of the water, such as the one present when the water was highly stratified and had shallow mixed layers, or when there have been calm weather and smooth seas. The authors show that a common southern California red tide dinoflagellate, *Gonyaulax polyedra,* was inhibited by low turbulence. In vivo chlorophyll fluorescence and cell numbers were used to determine the effect on cultures. After 2 days at a rotation speed of 60 rpm, the cells spun sluggishly in place and had lost their trailing flagella. After the speed was reduced, the cells recovered their swimming behavior, but did not grow. Several additional experiments were conducted at different speeds, and the turbulence and impact on the cultures were determined. Results indicate that turbulence is the cause of inhibition of red tides during moderate winds at sea.

USE OF CLAYS

YU, Z., J. Z. ZOU, AND X. MA. 1994a. Application of clays to removal of red tide organisms I. Coagulation of red tide organisms with clays. Chin. J. Oceanol. Limnol. 12:193–200.

Non vidi. Cited by Anderson (1996).

YU, Z., J. Z. ZOU, AND X. MA. 1994b. Application of clays to removal of red tide organisms II. Coagulation of different species of red tide organisms with montmorillonite and effect of clay pretreatment. Chin. J. Oceanol. Limnol. 13:62–70.

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YU, Z., J. Z. ZOU, AND X. MA. 1994c. Application of clays to removal of red tide organisms III. The coagulation of kaolin on red tide organisms. Chin. J. Oceanol. Limnol. 12:193–200.

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ACKNOWLEDGMENT—We thank Dr. George M. Padilla for helpful comments, and we are grateful to Mrs. Barbara B. Martin for serving as Consulting Editor.

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EVIDENCE OF CELLULOSE DIGESTION IN THE WOOD BORING ISOPOD *SPHAEROMA TEREBRANS*

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ABSTRACT: Sphaeroma terebrans *Bate is a widespread estuarine, wood-boring isopod found in red mangrove* (Rhizophora mangle) *forests of tropical and subtropical estuarine waters. Because it causes extensive damage to man-made structures in marine coastal zones and is resistant to common methods of wood preservation, it is important to understand fully how* S. terebrans *uses the wood into which it bores. Previous studies indicate that* S. terebrans *is primarily a filter-feeder and does not utilize bored wood as a nutritive substrate. However, laboratory feeding data obtained in this study indicate that juvenile* S. terebrans *specimens can survive on a diet of pure cellulose significantly longer than individuals given no food. In addition, enzyme assays show that digestive caeca homogenates from* S. terebrans *have active cellulose-digesting enzymes. Furthermore, SEM and TEM studies of this organism indicate that cellulose-like material is present in the hindgut of these organisms. These data taken collectively indicate that* S. terebrans *has the ability to use the wood as a food source.*

BEFORE the introduction of man-made wooden structures into the marine environment, mangroves and various types of driftwood were the only regularly available intertidal substrata for estuarine wood-boring organisms in Florida (Estevez,1978). Wooden structures introduced into the marine environment in more recent times have been besieged by wood-borers. Many methods of wood preservation have been implemented to combat the destructive activities of marine boring organisms. In spite of attempts at controlling wood borers, damage estimates of $50 million each year have been attributed to borer activity along U.S. coasts (Menzies and Turner, 1957; Hochman, 1973). The most common marine wood borers are bivalve mollusks (shipworms and mussels) and crustaceans (amphipods and isopods). The importance of wood to the borers varies among species, since some use the burrows only for habitat and protection while others use the wood as a source of food. (For a review of the marine borer literature prior to 1958, see Clapp and Kenk, 1957.)

The focus of the present study is on *Sphaeroma terebrans* Bate, a widespread estuarine, wood-boring isopod found in tropical and subtropical habitats. It flourishes in estuarine mangrove forests, such as those of the Tampa Bay area (the study site for this report). In a state-wide survey of more than 100 sites along the Florida coast, Rice and co-workers (1990) found active wood borers or historical evidence of attack by *S. terebrans* at 56% of freshwater sites and 33% of marine sites. Under natural conditions, *S. terebrans* may inhabit burrows in cypress, cedar, palm, and pine. It has been reported to attack *Juncus roemerianus* (black needle rush) and *Acrostichum aureum* (leatherfern) under estuarine and brackish conditions (Rice et al., 1990). *S. terebrans* is particularly common in the intertidal prop roots of *Rhizophora mangle* (red mangrove) under low salinity conditions. They can withstand several hours of exposure to air during low tide and typically will retreat into their burrows and remain inactive during these periods (Estevez, 1978). According to Simberloff and co-workers (1978), *S. terebrans* may indirectly aid the mangroves into which they burrow by helping them to survive wave action, as burrowing activity appears to initiate additional branching of aerial prop roots. Unfortunately *S. terebrans,* and the isopod *Limnoria tripunctata* (Menzies) also tend to bore into piers and pilings causing widespread damage in man-made structures of marine coastal zones (Boyle and Mitchell, 1978).

Wood-boring animals may use the wood they bore into in a variety of ways. For an animal to gain nutrition from the wood itself, it must be able to digest cellulose by using either symbiotic microorganisms (such as intestinal bacteria or protozoans) or endogenous cellulases. Endogenous cellulase activity for metabolic purposes is widespread in marine invertebrates (Elyakova, 1972; Foulds and Mann, 1978) including the obligate wood-boring teredinid ship worms *Bankia gouldii* (Dean, 1978) and *Teredo bartschi* (Turner, 1966), the wood-boring isopods of the genus *Limnoria* (Ray and Julian, 1952), and the omnivorous marine mysid *Mysis stenolepis* (Friesen et al., 1986).

Previous studies indicate that *S. terebrans* is primarily a filter-feeding isopod that does not require a nutritive wood substrate (Estevez and Simon, 1975; Rotramel, 1975). In addition, evidence indicates that the guts of *S. terebrans* and the obligate wood borers *Limnoria* spp. have no microorganisms that would assist them in the digestion of wood (Boyle and Mitchell, 1978). According to Estevez (1978), gut cellulases that are present in *S. terebrans* are thought to serve only for facultative activity, and even its anatomy suggests a filter-feeding lifestyle. Research on the digestive processes of this organism will allow an understanding of food requirements and feeding behavior of individuals and populations (Brunet et al., 1994). Furthermore, the question of whether or not *S. terebrans* uses its wood substrate as food is very important, as it is relevant to the development of better methods for wood preservation. Common methods of treating immersed wooden structures have proven ineffective against the boring activities of *S. terebrans,* and it is imperative to develop better wood treatment methods to reduce degradation of wooden piers and pilings.

Wood is a complex and variable substance depending upon its species of origin and environmental history (Parham and Gray, 1984). Natural wood is a complex material consisting of cellulose, hemicellulose, pentosans and lignin. The chemical composition and proportions of these substances varies however, between tree species and even within a given tree (Pettersen, 1984). Cellulose, the most abundant component of wood, is a polymer of $\beta(1-4)$-bonded anhydroglucose units arranged in strong, coiled microfibrils that provide support to plant cell walls (Pettersen, 1984). Few organisms have the enzymes necessary to digest cellulose since the $\beta(1-4)$ bonds are not affected by most carbohydrate-digesting enzymes. Many marine borers use their mouth parts or other body parts to grind the wood particles to a digestible size and then use enzymes in their gut to digest the exposed polysaccharides (Kirk and Cowling, 1984). The enzymes necessary to break the strong beta linkages between the glucose units in cellulose are called cellulases (Lehninger et al., 1993). These are the enzymes of interest in this research.

To observe cellulolytic activity for wood digestion, we compared *S. terebrans* tissue extracts to commercial preparations of cellulolytic enzymes from fungi and to homogenates of *Limnoria tripunctata* for their relative activity on two substrates. Sigma Cell microcrystalline cellulose and carboxymethyl cellulose were used in cellulase assays and are both documented in previous studies (Dean, 1978; Elyakova, 1972) as suitable substrates for measuring cellulase activity. In addition to the enzyme assays, feeding studies were performed to determine if *S. terebrans* juveniles could survive on cellulose particles alone. Finally, a scanning electron microscope was used to examine isopods mouth parts, and a transmission electron microscope was used to detect cellulose-like particles in the digestive tract of these organisms.

MATERIALS AND METHODS—*Specimen collection*—Specimens of *Sphaeroma terebrans* were obtained from prop roots of a natural stand of *Rhizophora mangle* lining the North side of the Gandy Causeway in Old Tampa Bay, Florida. The prop roots were split with scissors and animals were gently lifted out with forceps. Adult animals, including brooding females, were cultured in the laboratory to provide newly released juveniles for the feeding studies. The isopods were placed in polypropylene containers (35mm diam.) with Nytex screen sides (0.10–0.25mm mesh) to allow water flow. These containers were placed on plastic grids in 40 l aquaria that contained recirculating filtered natural seawater with a salinity ranging from 22 to 25 ppt, comparable to the salinity at the Gandy collection site. The isopods held in these aquaria were fed about every 3 d with a mixture of cultured *Tetraselmis* (green alga), organic matter from naturally occurring sediment, and Roti-rich food supplement (Florida Aqua Farms, Inc.). This food mixture is referred to as "regular food" below.

Feeding and growth experiments—Animals for the feeding experiments were newly released juveniles collected from adult culture containers. Two separate feeding experiments were performed. In the first experiment, which lasted for 10 wk, the juveniles were raised in six-well tissue culture dishes (one animal per well) with water changes every other day. The first six-well container held isopods that were given no food; these were the starvation control animals. The second six-well dish contained individuals that were fed a mixture of food identical to that given to the adults in the laboratory cultures (regular food). The third six-well container held individuals that were fed a 5% solution (w/v) of Sigma Cell 20 (microcrystalline cellulose in 20 μm particles, Sigma Chemical Co.) in deionized water. The isopods were fed and monitored for mortality, fecal pellet production, and molts every other day.

Because water quality was a problem in the small wells of the six-well containers, a second feeding experiment was attempted in which five isopods per treatment were placed in individual cylindrical polypropylene containers measuring 7 cm high by 4.5 cm in diameter with Nytex-screened windows. These cylindrical containers were, in turn, placed inside 8-l battery jars that containing 1 l of seawater. The seawater in the battery jars was monitored for temperature, which remained between 19.5° C and 21.5° C, and for salinity, which ranged from 20 to 25 ppt. The water was aerated and changed every 6 to 8 d. One battery jar contained five individuals that were given no food. A second battery jar contained five animals that were given regular food. A third battery jar contained five individuals that were fed a 5% solution of Sigma Cell 20 suspended in deionized water. The Sigma Cell 20 used in this trial was repeatedly rinsed with dilute hydrochloric acid to remove as much of the free glucose as possible and then frozen in 1.5 mL aliquots until needed. The isopods in the regular food and Sigma Cell 20 treatments were fed every 2 d, and all treatments were monitored for fecal pellets, molts, and mortalities. Each container was cleaned every two days to remove fecal pellets, molts, algae, dead animals and food build-up. This experiment lasted for 20 wk.

Cellulase enzyme assay—For the cellulase experiments, large adult animals were used to prepare tissue homogenates. Isopods were cold-narcotized and placed under a stereoscopic dissecting microscope. The head was held down, and the rest of the body was quickly pulled from the head with a pair of forceps. The digestive caeca were then removed and transferred to deionized water. These were homogenized in deionized water and, the supernatant obtained after centrifugation was used as the crude enzyme extract. In addition, standard cellulase enzyme (EC 3.2.1.4) from the fungus *Aspergillus niger* and homogenized *Limnoria tripunctata* (from whole animals) were prepared to run simultaneously for comparison in the cellulase activity assays.

Two substrates were exposed to the tissue homogenates and the standard cellulase: a 1% solution of carboxymethyl cellulose and a 1% solution of Sigma Cell 20. The cellulose substrates were repeatedly dialyzed and frozen prior to use to minimize the amount of glucose initially present. An assay for cellulase activity was performed using Nelson's method for reducing sugars (Nelson 1944, Alexander, et al., 1985) with a Spectronic 20-D spectrophotometer. A glucose control for all experiments was run to ensure that no reagents were contaminated with glucose. Any glucose detected in the controls was subtracted from the experimental values prior to data analysis. In addition, sodium azide was added to all tubes in each assay to inhibit the growth of bacteria. The spectrophotometric assay was performed on the tubes after incubations of 1-, 4-, and 8-hour time intervals. All absorbances from the spectrophotometric data were then converted to micromoles of sugar produced by using a glucose standard curve, according to Nelson (1944). The amount of sugar produced in each assay was converted to micromoles sugar per mg protein. Amounts of protein were determined following the Sigma procedure for protein determination (Sigma Chemical Co. Kit 690). This procedure involved mixing a protein sample with a diluted biuret reagent, followed with a Folin and Ciocalteu's Phenol Reagent. The protein concentration was then determined from a calibration curve formulated from spectrophotometric data obtained from a known protein (bovine serum albumin) dilution series.

Electron microscopy—Appendages, mouth parts, and digestive systems of *Sphaeroma terebrans* were dissected out and fixed in 2.5% glutaraldehyde for the scanning and transmission electron microscopes. After being dehydrated and critical-point dried, the body parts were sputter coated with gold and mounted whole on a specimen holder for examination on a scanning electron microscope (SEM). Samples for transmission electron microscopy (TEM) were postfixed in 2% osmium tetroxide, dehydrated to acetone and embedded in epon using propylene oxide as the transition solvent. Sections were cut on a Reichert-Jung Ultracut E using a diamond knife. Thin sections were stained in uranyl acetate and lead citrate and examined on a Hitachi 500 transmission electron microscope. Micrographs were examined for cellulose-like substances in the gut and caeca of these organisms. *Limnoria tripunctata* was prepared in a similar manner and used as a control, as they are known to be digesters of cellulose.

RESULTS—*Feeding and growth experiments*—The initial feeding experiment resulted in the death of five of the six unfed individuals by the fourth week. After 6 wk, all of the unfed animals, along with one each of those fed regular food and Sigma Cell 20 were dead. At the end of 10 wk, five of the animals fed regular food and five fed Sigma Cell 20 were still alive (Fig. 1A). Molting rates between the different treatments also varied. Figure 2A represents the mean number of molts per individual over the 10-week experiment. The control animals with no food produced no molts; the animals given regular food had an average of 2.5 molts per individual; and the animals fed Sigma Cell 20 had an average of 1.0 molts per individual.

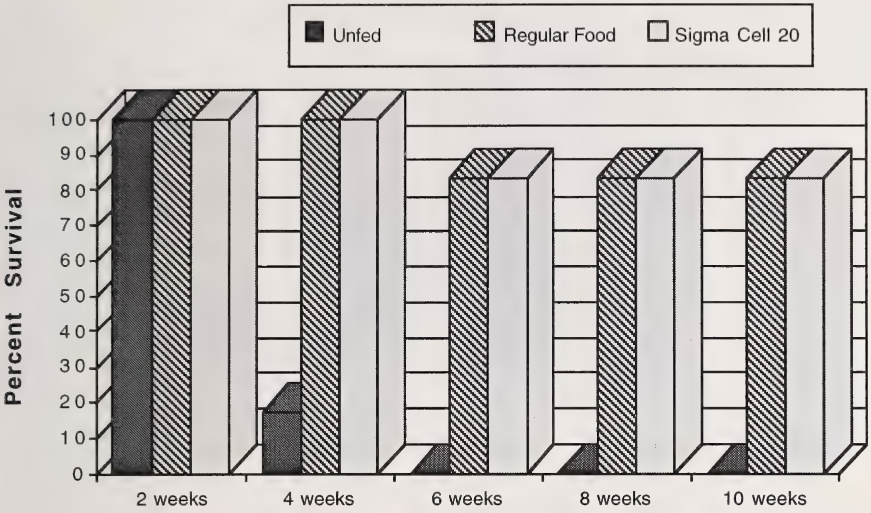
In the second feeding experiment, using larger containers, all control organisms (no food) died between 3 and 6 wk after the experiment began. One of the Sigma Cell fed animals died after 45 d, and a second Sigma Cell treatment death occurred after 69 d. All individuals fed regular food were still alive after 20 wk (Fig. 1B). The mean number of molts per individual over the 20-week period is presented in Figure 2B. The control organisms with no food showed a mean of 0.2 molts per individual while the animals fed Sigma Cell 20 produced 3.4 molts per individual; and the animals that were fed regular food produced 4.8 molts per individual after 20 wk. The molting rates for the latter two treatments were significantly higher ($P = 0.001$, F-test) than the rate for the unfed animals in the 20-wk experiment. In a combined analysis of the 10-wk and 20-wk experiments, both the regular food and Sigma Cell-fed treatments had molting rates that were significantly higher ($P = 0.0001$, F-test) than the unfed treatment, but the former two treatments were not significantly different from each other ($P = 0.095$, F-test).

Cellulase enzyme assay—In these experiments, carboxymethyl cellulose (CMC) and Sigma Cell 20 substrates were exposed to a standard cellulase enzyme and to *Limnoria tripunctata* and *Sphaeroma terebrans* tissue homogenates. The cellulase control was included to demonstrate that the substrates were digestible and to provide a standard with which to compare the activities of the isopod cellulases.

The cellulase assays produced variable results for the *Sphaeroma terebrans* and *Limnoria tripunctata* tissue homogenates but more consistent results with the purified cellulase used as a standard. In addition, there was some free glucose present in the standard cellulase, tissue homogenates, Sigma Cell 20, and carboxymethyl cellulose substrates. Corrections were made in the experimental results to account for this extra glucose (see METHODS). The data presented below represent two separate experiments with two replicates of each control and experimental solution.

The cellulose substrates (Sigma Cell 20 and CMC) were progressively broken down by the *Aspergillus* cellulase (Fig. 3A) with the Sigma Cell 20 being more resistant to digestion than the CMC. Digestion of CMC by isopod cellulases (Fig. 3B) was rapid during the first 4 h of exposure but slowed

A. Ten Week Study



B. Twenty Week Study

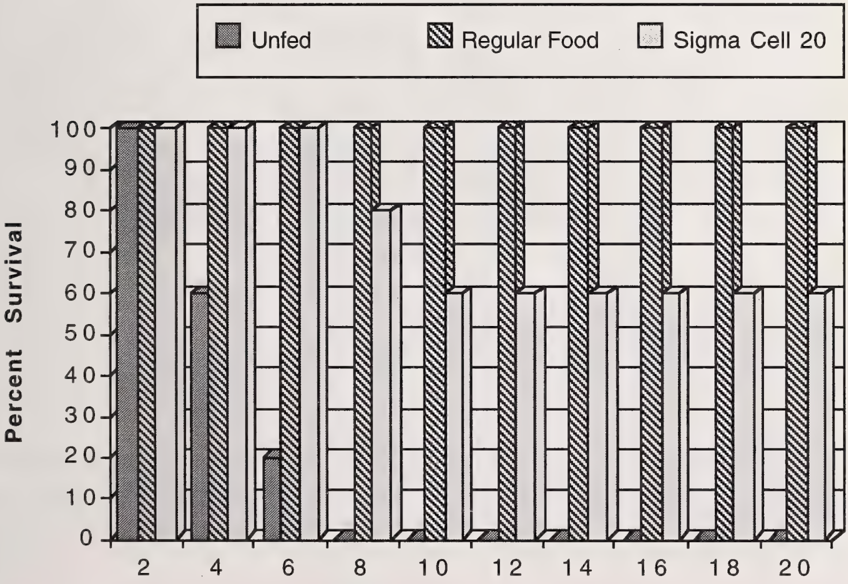
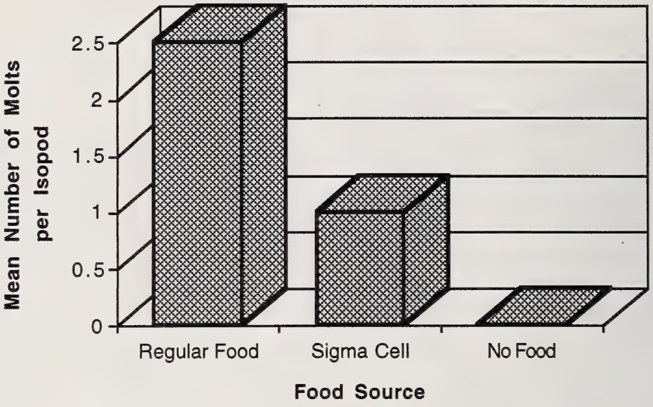


FIG. 1. Survival of *Sphaeroma terebrans* juveniles. A. 10-week feeding experiment (n = 6 per treatment); B. 20-week feeding experiment (n = 5 per treatment).


A. Ten Week Study

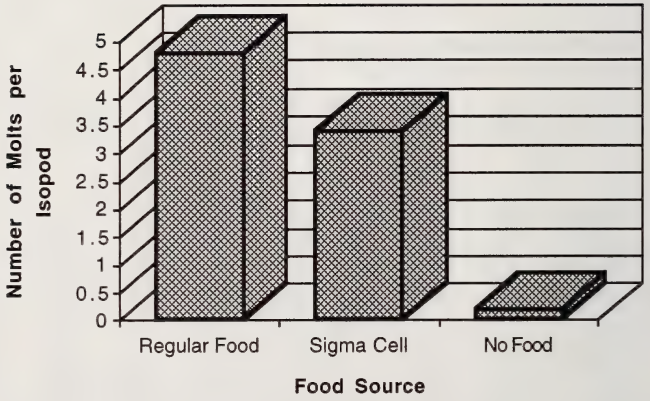
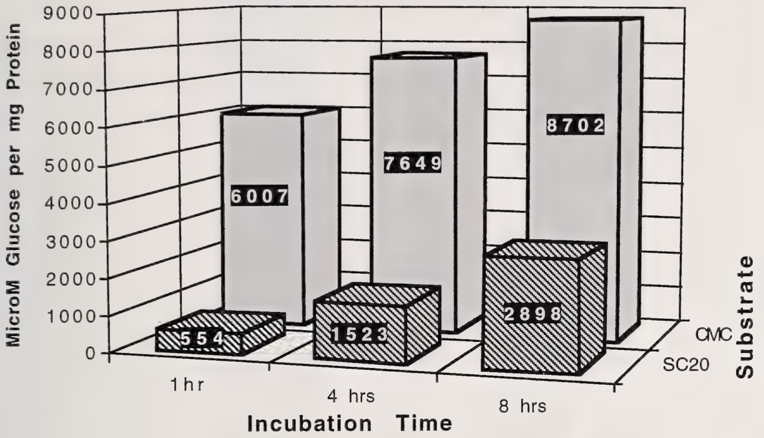

B. Twenty Week Study

FIG. 2. Mean molting rate for *Sphaeroma terebrans* juveniles. A. 10-week feeding experiment; B. 20-week feeding experiment.

thereafter. Figure 4 presents a summary of the mean rates of digestion of the two cellulose substrates by the three enzyme preparations. CMC was broken down by all three enzyme preparations, with *L. tripunctata* showing the highest amount of activity, liberating about twice as much glucose from the cellulose polymers as the standard cellulase. *S. terebrans* showed the lowest enzyme activity. All of the mean values for CMC are significantly different from each other (P = 0.0003, F-test). Sigma Cell 20 was only broken down by the standard cellulase and *L. tripunctata* tissue homogenates during the 8 hr incubations. The *S. terebrans* homogenate did not produce digestion products above background levels during the initial 8 hr of incubation. Due


A. Standard Cellulase

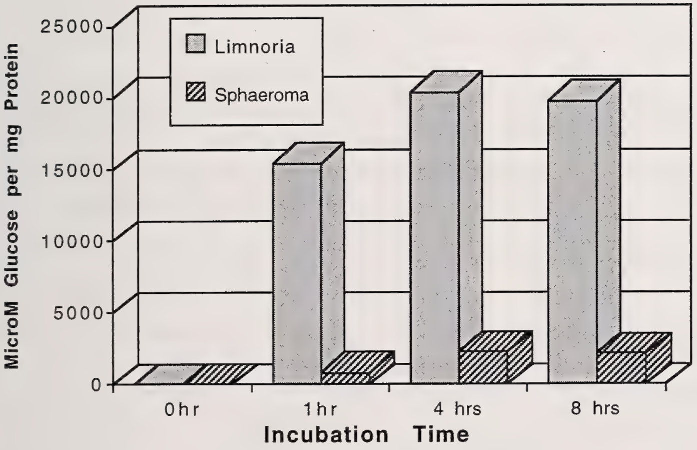

B. Isopod Cellulases

FIG. 3. A. Digestion rates from a representative experiment on two cellulose substrates, carboxymethyl cellulose (CMC) and Sigma Cell 20 (SC20), by standard fungal cellulase; B. Digestion rates of carboxymethyl cellulose by isopod cellulases.

to the large degree of variability in the Sigma Cell 20 results, the amounts of glucose released by the standard cellulase preparation and the *L. tripunctata* homogenate were not significantly different from each other (P = 0.098, F-test).

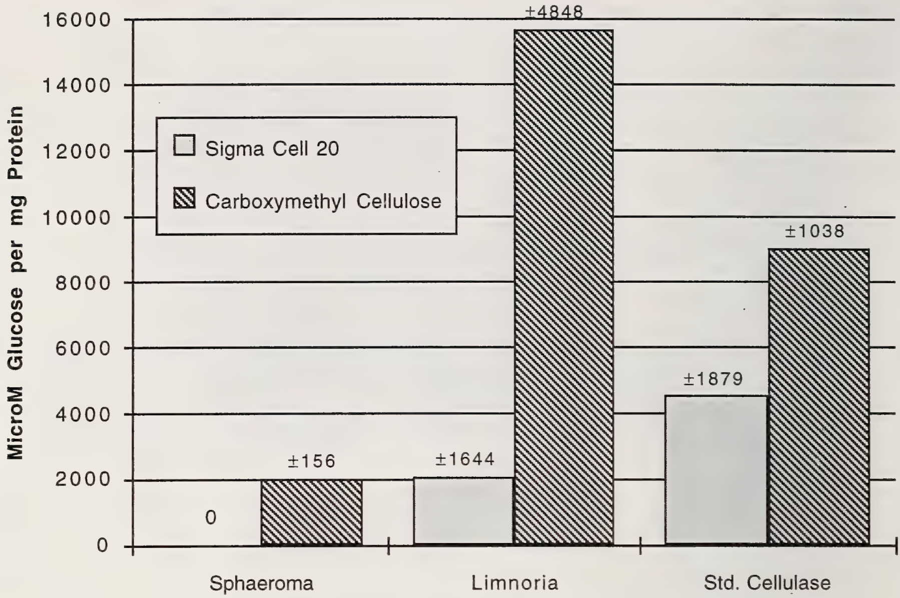


FIG. 4. Comparison of mean cellulose digestion rates (from two separate experiments) after 8 h of incubation among enzymes from *Sphaeroma terebrans*, *Limnoria tripunctata*, and commercially available fungal cellulase. Numbers represent one standard deviation.

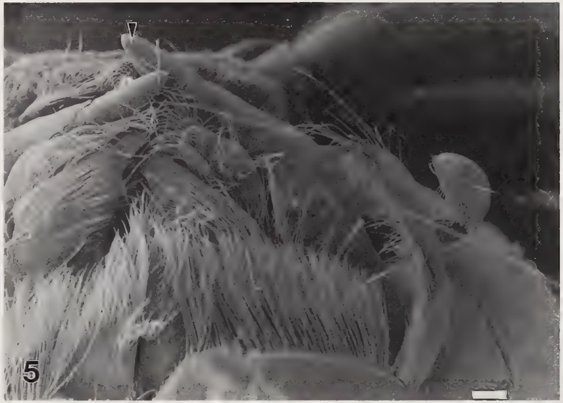
Morphology of appendages and digestive system—The anterior appendages of *Sphaeroma terebrans* are adapted for collection of particulate matter that enters the burrow along with the respiratory/feeding current produced by the pleopods. The mandibles are armed with strong cylindrical teeth as seen in Figure 5, that are used to excavate burrows in wooden structures. The two pairs of maxillae and single pair of maxillipeds are endowed with abundant setae (Fig. 6) that aid in transfer of trapped particulate matter from the setae on the pereopods into the mouth. Initial particle capture is accomplished by the first three pairs of pereopods, which have long, plumose setae directed ventrally from the ischium and merus of each appendage (Figs. 7 and 8). Trapped particulate material is removed from the setae of the pereopods by the maxillipeds at intervals during feeding.

Once particulate material enters the mouth, it travels through a short esophagus into a complex stomach containing multiple channels with spines which sort and direct the food particles depending upon size (Wägele, 1992). Large particles are directed toward the hindgut while finer particles are channeled toward the ventral filter system. The ventral filter system is composed of an anterior filter (clatri setarum anteriores) followed by a finer posterior filter (clatri setarum posteriores) that guards the entrance to the digestive caeca. Figures 9 and 10 depict representative sections through the posterior ventral filter system. In order to enter the ducts leading to the digestive caeca, ingested material must pass between the lateral elastic cushions and the inferomedianum posterium (imp in Figs. 9 and 10). The spinose border of the elastic cushion and the filtering apparatus of the clatri setarum posteriores are shown in Figures 11 and 12. What appears to be the walls of algal cells are visible between the spines in Figure 11. No particulate material was observed in sections of the digestive caeca or the ducts leading to them, suggesting that only molecular-size material is allowed to pass into these structures.

Electron micrographs of the hindgut contents of *Sphaeroma terebrans* revealed fibrous material that resembles wood fragments (Figs. 15 and 16). These animals were fixed immediately after removal from mangrove root tips and within 1 hr of collection from the field. Sections of the hindgut of *Limnoria tripunctata* showed numerous heterogeneous fragments of the wood on which they had been feeding (Figs. 13 and 14). No symbiotic bacteria or protozoans were seen in hindgut sections of either species.

DISCUSSION—Both feeding experiments performed in the laboratory on juvenile isopods resulted in the animals fed Sigma Cell 20 living longer than the unfed isopods (Figs. 1A,B). These results indicate that some nutrition is being gained from the Sigma Cell 20 food, and that these isopods are capable of using particulate cellulose as a food source under laboratory conditions. Although the molting rate of isopods given regular food was more rapid than those given only Sigma Cell 20, there was significant growth (as indicated by molting rate) in the animals with the Sigma Cell 20 diet when compared to the molting rate in the no food treatment. This suggests that the isopods were gaining enough nutrition from their cellulose food source to grow, although some essential ingredients needed for optimal growth were likely missing from their diet. No attempt was made to control or inhibit microbial growth in the laboratory experiments, and it is possible that microbial breakdown of the cellulose substrate might have been occurring.

John (1968) conducted feeding experiments with *S. terebrans* from the Kerala Coast (India) in which test animals were given either: 1) no food in artificial seawater; 2) filter paper in artificial seawater; 3) filter paper in natural seawater; or 4) seawater plus algae. He found that the unfed animals survived for an average of 12 d while the second and third treatments survived for an average of 43 d and 26 d, respectively. The seawater plus algae treatment had 70% survival after 120 d. John (1968, pg 4) concluded from these experiments that *S. terebrans* ". . . are able to subsist on cellulose." Kühne (1972) conducted feeding experiments using Australian wood-borers including *S. terebrans.* In these tests, juvenile *S. terebrans* were used in static dishes and provided with one of four combinations of natural celluloses and algae. Mean survival times in decreasing order were: 36 d for algae alone; 26 d for pinewood plus algae; 23 d for pine sapwood; 16 d for the starvation control; and 6 d for shipworm feces. Statistical analyses were not presented, but it was concluded that *S. terebrans* survives longer when given algae rather than wood as a food source (Kühne, 1972).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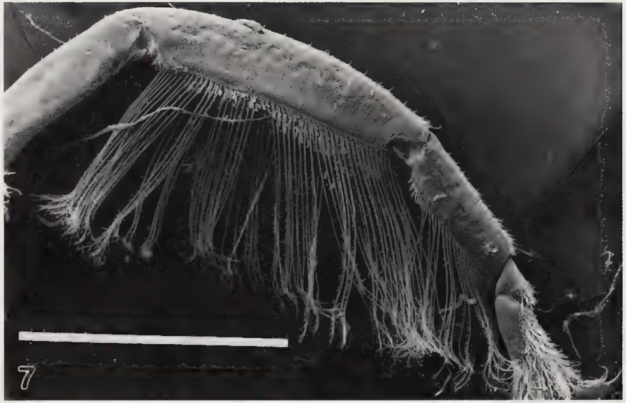
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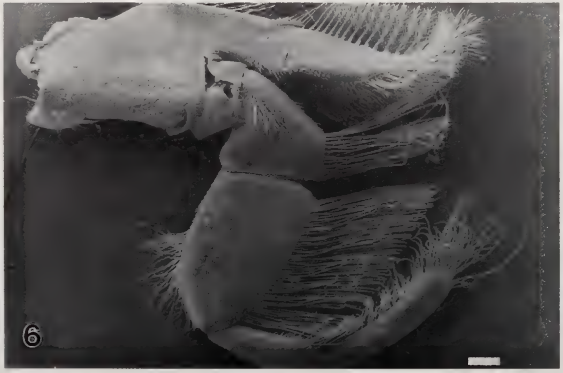
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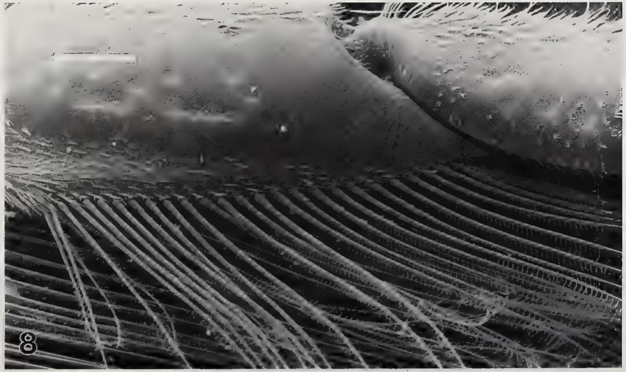
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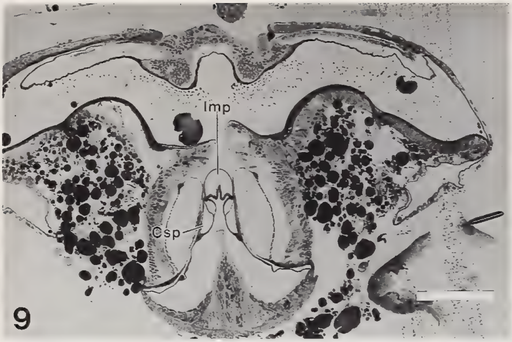
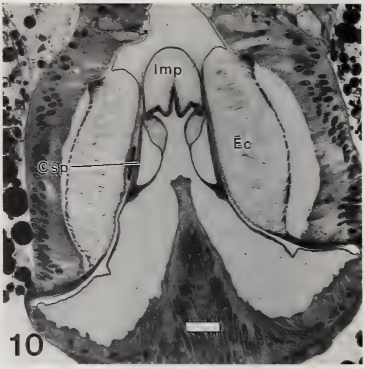
FIG. 5. *Sphaeroma terebrans,* mouth area of intact animal viewed from a posterio-ventral aspect. The tips of the mandibles are visible at the arrow. The maxilliped is located in the lower middle of the micrograph. Magnification marker = 0.10 mm.

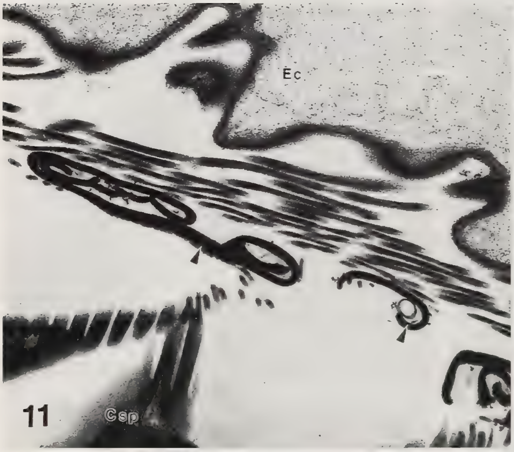
FIG. 6. *Sphaeroma terebrans,* excised maxilliped. The proximal article of the appendage is located in the upper left with the most distal article at the lower right. The setae on this appendage are used to clean material off the more posterior appendages. Magnification marker = 0.10 mm.

FIG. 7. *Sphaeroma terebrans,* excised first pereopod (walking leg) showing long setae used to collect suspended material from the water. The most proximal article of the appendage is to the left. Magnification marker = 1.0 mm.

FIG. 8. *Sphaeroma terebrans,* close-up of the joint between the merus and carpus of a pereopod showing details of the food collection setae. Magnification marker = 0.10 mm.







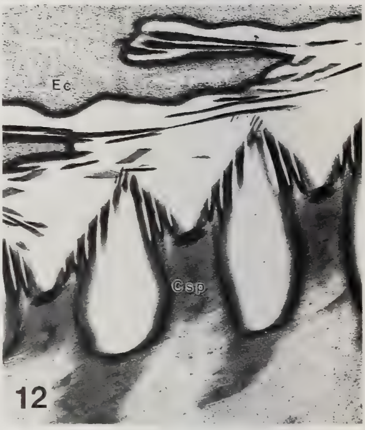


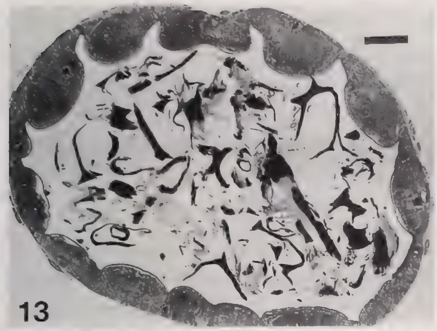
FIG. 9. *Sphaeroma terebrans,* light micrograph of a section through the stomach at the level of the inferomedianum posterium (Imp) and clatri setarum posteriores (Csp), where food material must pass to enter the hepatopancreas. Magnification marker = 0.05 mm.

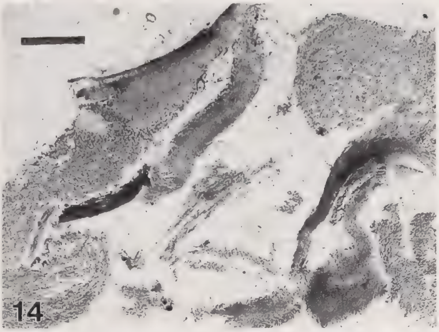
FIG. 10. *Sphaeroma terebrans,* light micrograph of the posterior stomach filter mechanism showing the inferomedianum posterium (Imp), clatri setarum posteriores (Csp) and the elastic cushions (Ec). Magnification marker = 0.01 mm.

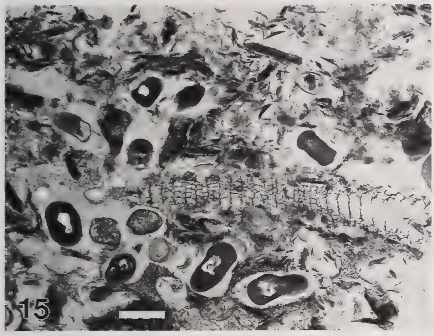
FIG. 11. *Sphaeroma terebrans,* electron micrograph of the filter mechanism that makes up the clatri setarum posteriores (Csp). The cell walls of algal cells (arrows) are visible diagonally across the middle of the micrograph between the Csp and the elastic cushion (Ec). Magnification marker = 0.50 μm.

FIG. 12. *Sphaeroma terebrans,* electron micrograph of the filter mechanism that makes up the clatri setarum posteriores (Csp) where it presses against the elastic cushion (Ec). Material that passes through this filter is transported to the hepatopancreas. Magnification marker = 0.50 μm.

Estevez (1978) tested the effects of burrow availability and food availability on the survival of adult *S. terebrans* from Florida. He found that animals survived longer when burrows (either natural or artificial) were provided and when food material was kept in suspension by aeration. This combination of conditions (burrows and suspended particulate matter) is







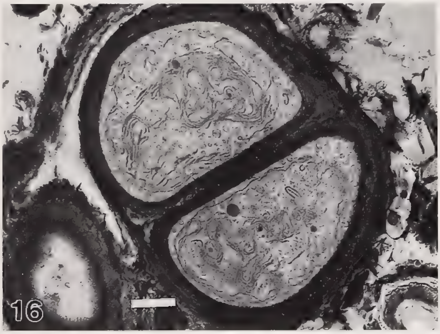


FIG. 13. *Limnoria tripunctata,* light micrograph of a section through the hindgut showing pieces of injested wood. Magnification marker = 0.02 mm.

FIG. 14. *Limnoria tripunctata,* electron micrograph of injested wood material from the hindgut of a well-fed animal. Magnification marker = 1.0 μm.

FIG. 15. *Sphaeroma terebrans,* electron micrograph of the hindgut contents of an animal removed from a mangrove root tip. Fibrous material that resembles wood fragments is visible throughout the micrograph. Magnification marker = 0.50 μm.

FIG. 16. *Sphaeroma terebrans,* electron micrograph of algal cells and fibrous material from the hindgut of an animal fresh from the field. Magnification marker = 0.50 μm.

found at field sites where *S. terebrans* establishes successful populations. In the present study, food material was not kept in suspension; and animals were not provided with burrows yet were able to survive and grow for extended periods of time (20 wk) if provided with cellulose or natural organic material. For juvenile animals under laboratory conditions, individuals seem to be capable of foraging successfully outside of a burrow.

El-Shanshoury and co-workers (1994) found that naturally occurring bacteria and fungi associated with the exoskeletons and burrows of *Limnoria lignorum* and *Sphaeroma serratum* had the ability to produce cellulases and that these enzymes might be important to the nutrition of these wood-borers.

John (1968) reported cellulose digestion by extracts prepared from the gut and the hepatopancreas of *S. terebrans* and concluded that this species may digest cellulose but needs additional nutrients from algae or diatoms for normal growth. In the present study, carboxymethyl cellulose was broken down rapidly by isopod and fungal cellulases, with enzymatic activity from the *S. terebrans* homogenate being the lowest of the three preparations tested. Sigma Cell 20 was digested more slowly than CMC by the standard cellulase and the *Limnoria tripunctata* enzymes whereas the S. *terebrans* homogenate showed no activity on this substrate after 8 h of incubation. Preliminary tests using longer incubation times (24 h) resulted in some Sigma Cell 20 digestion by the *S. terebrans* extract, but the experimental results were variable and need to be repeated using a more purified enzyme extract than that used in the present study. The fact that the cellulose digestion capabilities of *L. tripunctata* proved to be superior to those of *S. terebrans* supports the observation that wood is the primary food source of *L. tripunctata* (Ray, 1958; 1959), while *S. terebrans* also feeds on other suspended materials. These experimental data also indicate that further study is necessary to understand the importance of cellulose to *S. terebrans* in its natural environment.

The morphology of the digestive system in *Sphaeroma terebrans* from Florida appears to be similar to that described for the "generalized isopod" by Wägele (1992) and for *S. terebrans* from Kerala (India) by Johns (1968). Regardless of whether individuals feed on cellulose or other food, the ingested food is sorted in the stomach, only the finest colloidal or dissolved portion passing through the posterior filter and entering the hepatopancreas where endogenous enzymes are released (Brunet et al. 1994). The present study found no evidence from TEM micrographs for symbiotic bacteria in the digestive systems of *S. terebrans* or *Limnoria tripunctata.* Sections of hindgut from field-collected *S. terebrans* revealed cellulose-like material similar in morphological detail to the wood particles present in the hindgut of *L. tripunctata.* It is unclear if the cellulose-like particles in the gut of *S. terebrans* originated from bored mangrove root or from suspended material filtered from the water. Tracer studies using labeled mangrove wood might help to answer this question.

In conclusion, these data taken collectively suggest that *S. terebrans* has the capability to use the wood it bores as a food source. Further, it appears that this species can survive and grow for extended periods of time on a cellulose diet and that field specimens have cellulose-like material in their digestive systems. Further analysis of S. *terebrans* feeding behavior and digestive capabilities is warranted and would be useful in designing a wood preservative to will help minimize boring damage by this isopod.

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A COMPARATIVE STUDY OF STREAM HABITAT AND SUBSTRATE UTILIZED BY *CORBICULA FLUMINEA* IN THE NEW RIVER, FLORIDA

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Abstract: *Densities and length frequencies were different for* Corbicula fluminea *(Muller, 1774) collected from two habitat types, pool and run, in the New River (Suwannee Drainage), Florida. An area of 250 m^2 in each habitat type was searched and excavated to determine Asian clam densities. Densities were greatest in the pool habitat, ranging from 0 to 512 individuals/0.25 m^2 with a mean density of 26.9 individuals/0.25 m^2 (SD= 49.47). Densities in the run ranged from 0 to 260 individuals/0.25 m^2 with a mean density of 16.2 individuals/0.25 m^2 (SD= 23.96). In the pool habitat, densities were greatest in clay and coarse sand substrates. In the run habitat, densities were greatest in sandy mud and detritus sediments. Length ranged from 8 to 25 mm in the pool and 3 to 27 mm in the run. Mean length in the pool habitat was 18.7 mm (SD=2.15) and 17.9 mm (SD=3.84)in the run habitat. Mean length was significantly greater in the pool (n=2000, p=1.5E–09).*

The Bivalve, *Corbicula fluminea* (Muller, 1774), was first recorded in the Florida panhandle in 1960 (Schneider, 1964) and spread throughout the state reaching the southern portion of the peninsula by 1967 (Clench, 1970). Studies conducted by Bass and Hitt (1974a, 1974b) and Gottfried and Osborne (1982) in Florida have referred to the Asian clam as *C. manilensis* (Philippi, 1841); however, Morton (1979) provided electrophoretic evidence that suggests Asian clams in North America should be referred to as *C. fluminea.*

Investigators of *Corbicula fluminea* in the southeastern United States have documented the dispersal, population dynamics, and habitat preferences over large geographic areas (Jenkinson, 1979; Sickel, 1979; Hall 1984; Belanger et al., 1990; Stites et al., 1995). Some attention has been given to population dynamics and microhabitat usage in Florida. Gottfried and Osborne(1982) and Belanger and co-workers (1990) examined population dynamics with respect to substrate type, flow, and aquatic vegetation between upstream and downstream locations in the Wekiva and St. John's rivers, Florida, respectively. The focus of this study was to compare densities, substrate utilization, and length frequencies of *C. fluminea* between run and pool habitat types within the New River (Suwannee Drainage), Florida.

Study Area—The New River is a blackwater river located within the Suwannee River basin and forms the border between Union and Bradford Counties, Florida (Figure 1). The

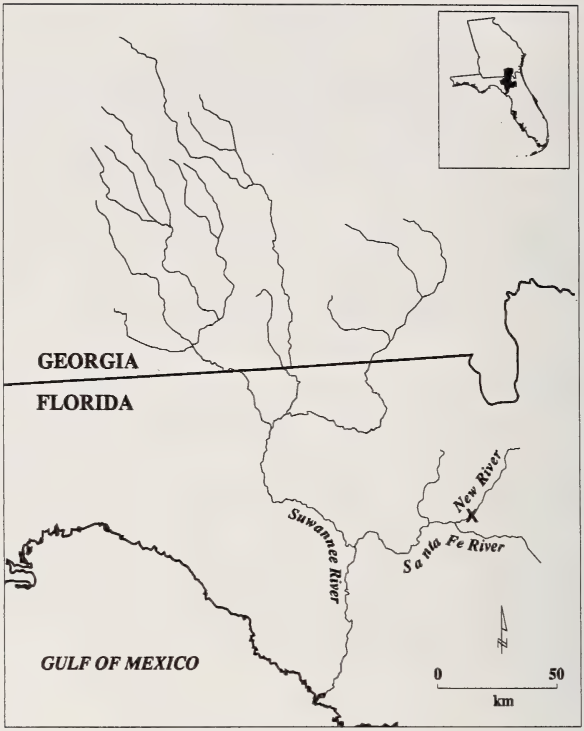

FIG. 1. New River, Florida. Study site location is denoted with an X.

study area, which is located approximately 300 m upstream of the Florida Highway 18 bridge (N 29° 55′ 34″, W 82° 24′ 35″), is comprised primarily of two physical habitat types, pool and run. The pool habitat is characterized by water 1.0 to 2.5 m deep. Sediments consist of hard packed clay and fine to coarse sands, with varying amounts of detritus. Run is the predominant habitat type in the New River. At normal flow the run is characterized by shallow water, ranging from 0.05 m to 0.5 m. Sediments consist of silts, fine to coarse sands, and varying degrees of detritus and logs.

METHODS—Densities were calculated from a census conducted over an area of 250 m^2 in each habitat type. Each habitat was divided into transects which were sampled with 0.25 m^2 quadrats. A total of 1000 quadrat samples were taken in each habitat type. *Corbicula fluminea* were removed first by hand from a search of the substrate surface and then by excavation of the substrate. Substrate was excavated to a depth of 10 cm when possible. Excavated material was sieved through a mesh size of 3 mm. All *C. fluminea* collected were counted.

A subsample of 2000 *Corbicula fluminea* were collected from the New River for length measurements. One thousand *C. fluminea* were collected in the pool habitat between 11 May and 16 May 1998 and 1000 were collected from the run habitat on 11 June 1998. Length was measured to the nearest mm with dial calipers for all specimens collected. Length is defined as the greatest distance from the anterior to posterior margin of the shell. A one-way ANOVA was conducted to compare mean lengths of *C. fluminea* between pool and run habitats.

RESULTS—A total of 26,866 *Corbicula fluminea* were found in the pool habitat and 16,207 were found in the run habitat. Densities in the pool habitat

TABLE 1. Ranges, number of individuals, and densities from the different sediment types within different habitat types.

Habitat/ sediment	Range/0.25 m^2	Number of individuals (%)	Density (#/0.25 m^2)	Percent habitat
Run	0-260	16207	16.22	
Clay pockets*	—	—	—	—
Detritus	0-199	1408 (9)	26.5	5
Coarse sand	0-176	2685 (16)	7.5	36
Fine sand	0-260	8222 (51)	18.25	45
Sandy mud	0-104	3892 (24)	28.75	14
Pool	0-512	26866	26.89	
Clay pockets	0-336	11771 (44)	47	25
Detritus	0-239	2251 (8)	12.75	18
Coarse sand	0-512	8051 (30)	32	25
Fine sand	0-290	4769 (18)	15	32
Sandy mud	1-10	12 (0.04)	4	<1

* Clay pockets with coarse sand substrate are not present in the run.

ranged from 0 to 512 individuals/0.25 m^2 and mean density was 26.9 individuals/0.25 m^2 (Table 1). Densities in the run habitat ranged from 0 to 260 individuals/0.25 m^2 and average density was 16.2 individuals/0.25 m^2. Densities were different between sediment types within a habitat and within sediment types between habitats (Table 1). In the pool, densities were greatest in clay pockets with coarse sand and coarse sand sediments. In the run, densities were greatest in detritus and sandy mud habitats.

Shell length ranged from 8 to 25 mm in the pool and 3 to 27 mm in the run (Figure 2). Mean length in the pool habitat was 18.8 mm (SD = 2.15) and 17.9 mm (SD = 3.84)in the run habitat (Table 2). *Corbicula fluminea* were significantly larger in the pool habitat (n = 2000, p = 1.5) (Table 3).

DISCUSSION—Greater densities and overall numbers of individuals were found in the pool. The differences in overall abundance may be attributed to habitat stability (Payne et al., 1989). During periods of low precipitation and higher air temperatures, water levels in the New River drop, exposing approximately half of the channel in the run. The remainder of the run is between 2 and 15 cm deep. The pool habitat has a water depth of at least 1 m all year. Reduction in the water level of the run severely reduces the habitat available. McMahon (1983) stated that periodic droughts and aerial exposure of *Corbicula fluminea* in lotic systems typically results in high mortalities and reduces population densities drastically.

In the pool habitat, greater densities of *Corbicula fluminea* were found in clay pockets with a coarse sand layer and in coarse sand substrate (Table 1). These two substrate types made up half of the habitat in the pool and occurred in the center of the channel. Belanger and co-workers (1990) reported the greatest densities of *C. fluminea* were collected in sandy sediments with low organic content. In the run habitat, detritus, sandy mud, and fine

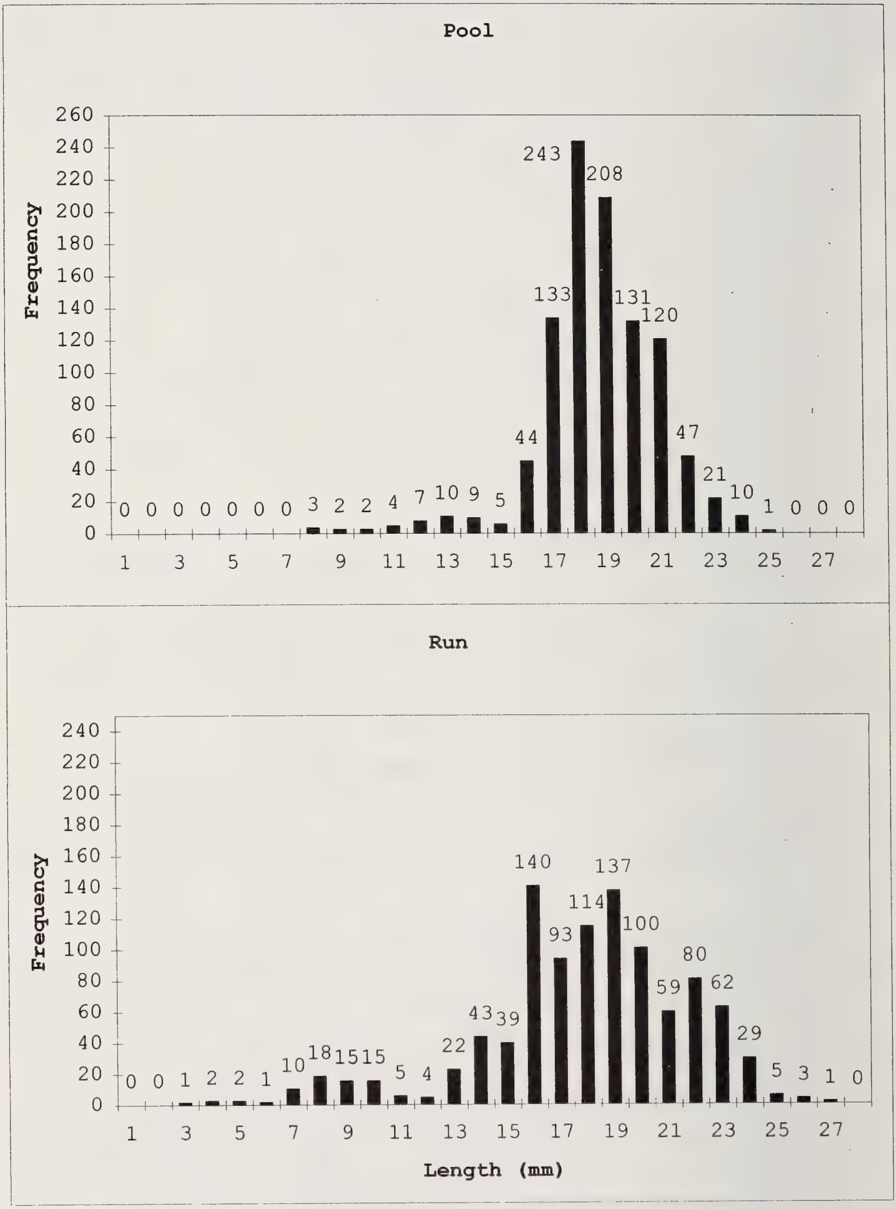

FIG. 2. Length-frequency distribution of *C. fluminea* from pool and run habitats, in the New River, Florida.

TABLE 2. Descriptive statistics for individual lengths of *C. fluminea* in each habitat in the New River, Florida.

	Run (mm)	Pool (mm)
Mean	17.91	18.76
Standard error	0.12	0.07
Median	18	19
Mode	19	18
Standard deviation	3.84	2.15
Sample variance	14.72	4.64
Kurtosis	1.09	3.12
Skewness	−0.86	−0.80
Range	24	17
Minimum	3	8
Maximum	27	25
Sum	17914	18759
Count	1000	1000
Largest (1)	27	25
Smallest (1)	3	8
Confidence level (95.0%)	0.24	0.13

sand had higher densities of Asian clams (Table 1). Belanger and co-workers (1985) reported *C. fluminea* in laboratory and field studies preferred fine sand sediments that were organically enriched. Payne and co-workers (1989) reported that substrate stability may be vital to structuring of lotic populations. Stability in the pool may be provided by the protected clay depressions filled with coarse sand. In the run, the sandy mud and detritus areas remain underwater during periods of low flow providing habitat stability.

During October 1997, visual observations from sieved quadrats in the run contained small (<5 mm) *Corbicula fluminea*; however, two weeks later, sieved quadrats in the pool contained no small *C. fluminea.* Quantitative data collected in May and June revealed similar results. Individuals ranging in length from 3 to 7 mm were absent from the pool habitat but were present in the run. Payne and co-workers (1989) noted that passive transport of veligers was reported in many studies and was evident in length frequencies

TABLE 3. Single factor ANOVA to test for differences in mean lengths of *C. fluminea* from each habitat in the New River, Florida.

Habitat	Count	Sum	Average	Variance
Run	1000	17914	17.91	14.72
Pool	1000	18759	18.76	4.64

Source of variation	SS	df	MS	F	P-value	F crit
Between groups	357.01	1	357.01	36.88	1.5E-09	3.84
Within groups	19341.52	1998	9.68			
Total	19698.54	1999				

of juveniles in downstream sites. The lack of juveniles in the upstream site (pool) may be related to downstream passive transport.

Another possible explanation for the overall low numbers of small individual *Corbicula fluminea* in this study may be predation. Bass and Hitt (1974b) reported that in the Suwannee and Santa Fe Rivers, Florida, *Corbicula* was a food source for the redear sunfish, *Lepomis microlophus* (Gunther, 1859) and the spotted bullhead, *Ameiurus serracanthus* (Yerger and Relyea, 1968). McMahon (1983) summarized a list of fish known to prey on *C. fluminea.* The following fish from McMahon (1983) are present within the Suwannee River Drainage (Lee et al., 1980): bluegill, *Lepomis macrochirus* (Rafinesque, 1819); spotted sucker, *Minytrema melanops* (Rafinesque, 1820); sturgeon, *Acipenser* spp.; and channel catfish, *Ictalurus punctatus* (Rafinesque, 1818). The common carp, *Cyprinus carpio* (Linnaeus, 1758); freshwater drum, *Aplodinotus grunniens* (Rafinesque, 1819); smallmouth buffalo, *Ictiobus bubalus* (Rafinesque, 1818); black buffalo, *I. niger* (Rafinesque, 1820); and blue catfish, *I. furcatus* (Lesuer *in* Valenciennes, 1840) also prey on Asian clams but do not occur within the Suwannee River Drainage. Size selective predation on *C. fluminea* (< 9 mm in length) has been documented for fish and crayfish (Britton and Murphy, 1977; Covich et al., 1981). Herod and co-workers (1997) observed blue catfish, *Ictalurus furcatus,* feeding on Asian clams from 1 to 12 mm in length with a greater abundance of individuals being 3 to 7 mm in length. Observations while snorkeling and SCUBA diving at the study site on the New River indicated that fish and crayfish were more abundant in the pool habitat. No crayfish and few fishes were observed in the run habitat. Predation by fish and crayfish may play a role in structuring the size distribution of *C. fluminea* collected from the pool habitat.

The length frequency distributions presented in this study are similar to the distributions presented by Gottfried and Osborne (1982) from the Wekiva River, Florida. They did not account for the low numbers of small (< 10 mm) Asian clams. The lack of juvenile *C. fluminea* in this and other studies may be due to a factor of the population, the environment, or a combination of factors.

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REVIEW

Ann M. Penrose and Steven B. Katz, *Writing in the Sciences,* St. Martin's Press, New York, 1998, xiii +321. Price, $26.50 net., paper.

SCIENTISTS communicate or try to as a major part of their lives. An article by Seiken (1992) suggested that more than 40,000 scientists annually apply for research funding from two government agencies. This statistic and others remind us of the importance of written (and oral) communications. What is fascinating is the number of books that do not address the special problems that scientists face in written communications, writing for peers and writing for money.

The authors, members of the English Department at North Carolina State, have taught a course in scientific writing for a number of years, and this book (as well as well-trained students) is the result of their efforts.

The textbook is divided into two parts: Scientific Conventions and Sample Research Cases. The first part addresses background information, then focuses on reading and writing research reports, writing research proposals, preparing conference presentations, communicating with public audiences, and ethics in scientific communications. This material has exercises in the body of the text and at the end of each chapter. The second part looks at three case histories (Research on the "ulcer bug," predatory algae, and supernova remnants). The latter section includes reprints of significant papers on the subject, as well as a research proposal submitted by Burkholder and Rublee for support of their pioneering research on *Pfiesteria piscicida,* a predatory alga.

This is a well organized, well written book, and it deserves serious consideration by researchers and those who try to teach communication in science.—Dean F. Martin, University of South Florida, Tampa, FL.

LITERATURE CITED

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Biological Sciences

THE HERPETOFAUNA OF THE KAMPONG

WALTER E. MESHAKA, JR.

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ABSTRACT: *Fourteen reptile and three amphibian species were present at the Kampong, a four ha tropical garden in Coconut Grove, Dade County, Florida. Only four species were native, indicating that the herpetofauna of the Kampong was an artifact assemblage dominated by exotic species, mostly small-bodied lizards. Eleven of the 13 exotic species present were established and comprised 42% of the terrestrial and arboreal exotic herpetofauna of Dade County. A new species for North America,* Mabuya multifasciata *(Lacertilia: Scincidae) of southeast Asia was recorded at the Kampong. The herpetofauna of the Kampong reflected the changing herpetofaunal community of southern Florida. The protected nature of the Kampong and recent acquisitions of adjacent land favor the persistence of both native and exotic herpetofauna.*

THE KAMPONG is a nearly four ha tract of land located in Coconut Grove, Dade County, Florida. From 1916 until his death in 1954, the Kampong was the residence of Dr. David Fairchild who, as Chief of the Seed and Plant Introduction Section of the United States Department of Agriculture, introduced and propagated many species of tropical plants in connection with his many foreign plant expeditions. The estate garden was purchased in 1963 by Mr. and Mrs. Edward Cleaveland Sweeney, and in 1984 the property was deeded to the National Tropical Botanical Garden and became listed on the National Register of Historic Places. To date, this rectangular piece of property overlooking Biscayne Bay remains a botanical garden and is used for research and education. Habitats on the property range from mangrove swamp which lines a boat channel connected to the bay to uplands which are planted with many tropical fruit trees and some native species. Much of the land is approximately 6–7 m above sea level on limestone of the Atlantic Coastal Ridge. The historical and protected status of the Kampong makes the site well-suited for long-term studies. In this connection, I was able to make repeated visits and compile a herpetofaunal species list of the Kampong, which I compare here to the list of exotic species known from Dade County.

MATERIALS AND METHODS—Three diurnal visits (spring, summer, and fall) and one nocturnal visit (summer) were made to the Kampong between October 1996 and September 1997. One diurnal visit was made in April 1998. Rocks and logs, used as borders for mulch beds, were rolled over in search for animals. Bark and loose palm boots were peeled and leaf litter was searched for animals. Buildings and trees were searched at night for nocturnally active species and, for all species, habitat or microhabitat associated with capture was noted. Records of species were documented by voucher specimens. During a single walk around the grounds of the Kampong, I measured perch heights of four species of *Anolis*. A few individuals of *A. sagrei* were excluded from the count because of uncertainty of their sex. A single individual of *M. multifasciata* was deposited in the National Museum of Natural History. All other vouchers were deposited in the Everglades Regional Collections Center in Everglades National Park. Observations of species by knowledgeable persons were included in this paper.

RESULTS AND DISCUSSION—Fourteen reptile and three amphibian species were recorded from the Kampong. Most of the species were anoles and geckos of small to moderate body size. Less than one-quarter of the species recorded were native (Table 1). *Coluber constrictor* was the most frequently encountered native species, with one to four individuals observed during each diurnal visit, often actively foraging along the edges of plantings and around the bases of trees where *Anolis* spp. were present. *Elaphe guttata* was occasionally seen by Kampong staff but not observed during this study. Suitable habitat, the increased size of contiguous habitat through purchases, and the protected status of the Kampong's fauna have proven favorable for these medium to large-bodied snakes, which would otherwise fare less well with frequent human contact in a more urbanized setting. Two adult *Diadophis punctatus* were observed; however, the small body size and retiring habits of this species, and the presence of extensive beds of mulch and leaflitter underestimated the actual abundance of this species. *Sphaerodactylus notatus* had the most restricted distribution at the Kampong. During the day, individuals were regularly observed foraging in and out of the leaf litter exclusively along a 100m trail through mangrove habitat bordering the north side of the boat channel. This species does not persist in urbanized areas of southern Florida.

Eleven of the 13 exotic species recorded at the Kampong were established at the site and represented 42% of the established exotic herpetofaunal species in Dade Co., exclusive of aquatic species (Butterfield et al., 1997; Meshaka et al., 1997). *Anolis* was the best represented exotic genus. Using the terminology of Williams (1983) and the observations by Williams (1969, 1983) and Collette (1961), trunk-ground (*A. sagrei*), trunk (*A. distichus*), trunk-crown (*A. porcatus*), and crown giant (*A. equestris*) ecomorphs were present throughout the property. Preliminary data (Table 2) indicated that, despite the mix of a mostly Cuban anoline fauna with a single Bahamian

TABLE 1. Reptiles and amphibians found at the Kampong, Dade County, Florida. * = voucher specimen.

Species	Native established	Exotic established	Exotic observed
Reptilia			
Iguanidae			
*Anolis distichus**		X	
A. equestris		X	
*A. porcatus**		X	
*A. sagrei**		X	
Iguana iguana			X
Gekkonidae			
Gekko gecko			X
*Hemidactylus garnotii**		X	
*H. mabouia**		X	
*Sphaerodactylus notatus**	X		
Scincidae			
Mabuya multifasciata		X	
Colubridae			
Coluber constrictor	X		
Diadophis punctatus	X		
Elaphe guttata	X		
Leptotyphlopidae			
*Ramphotyphlops braminus**		X	
Amphibia			
Bufonidae			
Bufo marinus		X	
Hylidae			
Osteopilus septentrionalis		X	
Leptodactylidae			
Eleutherodactylus planirostris		X	
Total	4	11	2

species (*A. distichus*), the members of this anole community maintained perch heights generally in keeping with their ecological positions in the West Indies (Collette, 1961; Williams, 1969, 1983).

The trunk-crown position is also occupied by *A. carolinensis,* which is morphologically and ecologically most similar to *A. porcatus* (Collette,

TABLE 2. Perch heights of *Anolis distichus, A. equestris, A. porcatus,* and *A. sagrei* (male, female, and juvenile) at the Kampong from 1600–1730 hrs on 2 August 1997.

Perch height (cm)	*A. distichus*	*A. equestris*	*A. porcatus*	*A. sagrei*
0–60	2	0	0	9,24,55
60–105	3	0	0	18,9,2
105–180	9	0	0	13,5,0
>180	0	3	6	3,0,0
Total	14	3	6	43,38,57

1961; Ruibal and Williams, 1961; King, 1966). Potential for competition and/or hybridization with *A. porcatus,* and the saurophagous habits of *A. equestris* (Garrido, 1996), *A. sagrei* (Campbell and Gerber, 1996), and *A. porcatus* (Meshaka et al., 1997), are all factors that could explain the apparent absence of *A. carolinensis* at the Kampong.

Geckos had almost as many species as anoles at the Kampong (Table 1). Both *Hemidactylus garnotii* and *H. mabouia* were present. Because *H. mabouia* is known to replace congeners, including *H. garnotii* in Florida (Meshaka et al., 1994; Meshaka and Moody, 1996), its apparently equal abundance with *H. garnotii* suggests recent colonization. During this study, one large calling male of *Gekko gecko* inhabited the large *Ficus bengalensis* at the entrance gate (Schokman, 1998). This species is experiencing a growing presence in Dade Co., including nearby South Miami (WEM, Unpubl. data). Thus, if not already established, colonization of the Kampong by *G. gecko* seems inevitable.

In light of the growing ubiquity of *Iguana iguana* in southern Florida and the abundance of flowering plants and fruit trees at the Kampong, the recent and repeated observations of two individuals on the site were not surprising and, like *G. gecko,* a prelude to predicted colonization of the site. The Mexican spiny-tailed iguana (*Ctenosaurus pectinata*) is common along the rocky environs of Cutler Bay south of the Kampong, and, I believe, it will eventually colonize the Kampong.

Mabuya multifasciata, a livebearing skink from southeast Asia, was recorded for the first time in the United States on the grounds of the Kampong, where it was first observed at least as early as 1990 (Schokman, 1998). Extensive field observations in 1972 and 1974 revealed no individuals (Lodge, 1998). This species has become noticeably more numerous at the Kampong since Hurricane Andrew in 1992 (Schokman, 1998). The species was identified from a 35 mm slide by Aaron Bauer and from a voucher specimen (USNM 523790) by George R. Zug and Ronald Crombie. Individuals were observed basking on a cement walkway and foraging in the leaf litter when the ambient temperature was at least 26–27 °C. Adults were philopatric and reliably seen foraging or basking near their refuges, which were in the spaces provided between branches stacked within the mulch. In March 1998, a pair was daily seen within a few cm of each other at the same spot for a few weeks on warm days (Lodge, 1998). A large individual was once observed subduing a large scorpion in its mouth.

Dispersal from the pet trade best explains the colonization of the Kampong by *M. multifasciata,* which is popular in the exotic pet trade, commercially available in large numbers, primarily from Vietnam, and inexpensive (Bartlett, 1998). This species often appears on price lists of exotic pet dealers, although the species name is often confused. The distribution of *M. multifasciata* in Coconut Grove is poorly known beyond the confines of the Kampong; however, the species is present at two residences across the street from the Kampong and on adjacent newly acquired land north of the Kampong. All sites share sunny, open patches with large, mulch borders.

The herpetofauna of the Kampong reflected that of southern Florida which is characterized by increasingly new exotic species, primarily lizards. The Kampong's protected status, large size, and extensive greenery, even if different from natural habitats, provided a haven more so for exotic than native species in an otherwise increasingly urbanized landscape.

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ECONOMIC CONSIDERATIONS IN THE REMOVAL OF COPPER AND CHROMIUM FROM ELECTRONIC WASTES

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Abstract: *An analysis is made of the cost of processing etchant wastes from electronic industries using a process of reduction with sugar, followed by chelation and extraction with a cloud-point technique. This less-common extraction method was previously used to extract chromium(III) ion from aqueous solution. Using a nonionic surfactant solution and 8-hydroxyquinoline (or a derivative), a chromium(III) complex and unreacted chelating agent were extracted into the micellar phase at a temperature above the cloud-point temperature within two hours. The molar ratio, pH, temperature and hydrophobicity of the chelating agent were factors determining the extraction efficiency. Extraction efficiency was improved to 99%, and chromium concentration was reduced from 55 ppm to less than 1 ppm when excess chelating agent was used at pH 5.5 at 70° C. Analysis indicates the procedure could be much cheaper than current hazardous waste disposal practices.*

Tons of chromium are released to the environment through many industries: metal finishing, petroleum refineries, steel industries, inorganic chemicals production, textile manufacturing, pulp production process, electronic circuit printing, leather process, etc (Weltrowski et al., 1996). Current methods for elimination of chromium ion include chemical precipitation, ion exchange, sorption, and electro-deposition (Weltrowski et al., 1996). The main limitation of these technologies is a low efficiency for removal of trace levels of metal ions. Several alternative methods are under development for trace level metal remediation. Two of these are cloud-point extraction and bioadsorption.

Aqueous waste from computer board etching processes from a typical electronic firm would be an acidic solution containing chromium(III), chromium(VI), copper(II), and sulfate ion. The cost of disposal of this waste through storage is thought to be at least $300/drum. Previous research has reported methods for removal using a combination of chelation and cloud-point extraction of the chelated copper (Wang et al., 1996). With chromium(VI) a reduction step is required, and we demonstrated that sugar was an effective reducing agent (Wang et al., 1999a) and that the resulting Cr(III) species could be separated by the same approach as was used for copper (Wang et al., 1999b,c). Using the procedures described above, copper concentrations could be reduced from 100 ppm to 0.5 ppm and chromium concentrations from 1000 ppm to 1 ppm. This would satisfy the waste discharge limit in State of Florida (Swihart et al., 1984).

On the other hand, the U.S. Environmental Protection Agency, as well as many state programs, has many strict requirements for centrifying manufacturing facilities for treatment, storage, and disposal of hazardous wastes. For example, the industrial waste discharge requirements for electroplating are specified (EPA, 1986). These requirements can be more demanding than the requirements in place for the State of Florida (Swihart et al., 1984) for industries with discharges in excess of 38,000 liters per day. Because of these restrictions, industry has drastically reduced the amount of hazardous waste through several approaches, including process modification ("green chemistry"), recycling, process modification, and changes in solvent use.

Typically, treatment of chromium(VI) wastes involves four steps: reduction to chromium(III), precipitation of the hydroxide at high pH, allowing the precipitate to settle, and disposal of the dewatered sludge (Kratochvil et al., 1998). Water containing low concentrations of chromium(VI) can be treated with ion-exchange resins, but the cost of the resins limits the utility of this approach (Kratochvil et al., 1998).

There is room for improvement in attaining an economical, successful "one-pot" method for direct removal of chromium(VI) species from aqueous solutions. Emulsion liquid membrane extraction, for example, could not reduce chromium(VI) to less than 0.5 ppm (Salazar et al., 1990). The chemical reduction of chromium(VI) could be economical and efficient. More recently, a report of the removal of chromium(VI) by use of seaweed, gathered from Florida beaches, was described (Kratochvil et al., 1998). The authors described the conversion of washed seaweed to an ion exchange material that was also capable of reducing chromium(VI) as well as removing the resultant chromium(III). The percent recovery seemed to be less than was reported for our cloud-point extraction method (Wang et al., 1999b,c)

Cloud-point extraction is based on cloud-point properties of a nonionic surfactant in aqueous solutions. Aqueous solutions of many nonionic surfactants become turbid when the solution is heated to a certain temperature called the cloud-point temperature (Tcp). Above this temperature, aqueous nonionic surfactant solutions undergo phase separation: the smaller detergent phase contains most of the surfactant, and the more voluminous aqueous supernatant contains amounts of surfactant close to its critical micelle concentration (CMC).

The cloud-point extraction has been applied to the extraction and/or preconcentration of a wide range of analytes (cf. Wang et al., 1999b). Cloud-point extraction of metal ions requires conversion of metal ions to hydrophobic complexes in order to be extracted into the micellar phase. Since Watanabe and Tanaka's (1978) report of nickel and zinc ions extraction, many chelating agents have been used to extract metal ions. One application of this technique is the preconcentration of trace amounts of metal ions as a step prior to their determination by atomic absorption spectrometry (Pinto

TABLE 1. Cost of sucrose in treatment of chromium (VI)-containing waste*

[Sucrose]/[Cr(VI)]	0.63	0.40	1.0	2.0	5.0	10.0
Sucrose, g	41	263	657	1,314	3,283	6,566
Cost, $**	0.01	0.05	0.13	0.26	0.67	1.31
Costs of storage, $	300	300	300	300	300	3000

* Calculations are based on 100 L of 1000 ppm Cr(VI).
** Price of food-grade sucrose was $0.20/kg.

et al., 1994). Chromium(III) ion extraction is seldom reported because of the slow formation rate of its complexes in aqueous solutions, but we reported conditions for achieving good extraction of chromium(III) using cloud-point extraction (Wang et al., 1999b,c).

The present report considers the economics of the reduction/chelation/cloud-point extraction approach that we have described above. For the environmental application of this remediation method, several economic factors need to be considered, and this is a start.

MATERIALS AND METHODS—The methods used are described in detail elsewhere (Wang et al., 1996, Wang, 1997, Wang et al., 1999a,b,c). Cost data were obtained from catalogues of appropriate vendors.

RESULTS AND DISCUSSION—The overall cost depends upon the cost of several components plus energy costs, and these are constantly changing, but an effort was made to provide a general approach to the calculation of costs. We assumed that 100 L of aqueous waste was involved with 1000 ppm (1.92×10^{-2} *M*) of chromium(VI).

Cost of sugar—For one barrel (100 L) of aqueous wastes, the minimum amount of sucrose is 0.12 mole (4.1 g). If excess sucrose is used, such as [sucrose]/[Cr(VI)] of 0.4 (Table 1), the sucrose amount is 0.77 mole/100 L or 263 g/100 L. Table 1 indicates that the cost of sugar is very small and can be neglected. Excess amounts of sucrose can be used to increase the rate of chromium(VI) reduction because it is cheap. However, an overdose of sucrose in wastewater could lead to a potential pollutant that would assist growth of blue green algae (cyanobacteria), were the water to pass all other criteria for purity. The sucrose amount was kept as low as possible based on the pH and temperature in the treatment process. At pH of 0.6 and room temperature (23°C), a [sucrose]/[Cr(VI)] ratio of 5 reduces 1000 ppm chromium(VI) to 0.5 ppm in less than one day (time is 130 minutes; Wang et al., 1999a) and the cost is $0.67/100 L. For a molar ratio of 2, the time is three days to reduce chromium(VI) to less than 0.5 ppm. In Florida, the temperature outside is about 30–40 °C and the chromium(VI) reduction reaction is fast. The convenient process of chromium(VI) reduction is the addition of sufficient sucrose to the acidic waste from electronic firms.

Cost of energy—Temperature is a key factor for the cloud-point extraction and chromium(VI) reduction. In Florida, the reduction temperature could be kept at 23–40 °C by solar heating. The cloud-point extraction is an energy-consuming step. The extraction temperature is above the solution's cloud-point temperature (Tcp). The lowering of the Tcp is a way to saving the energy. The extraction temperature for chromium (III) and copper(II) ions is adjusted to the temperature achieved by solar energy. Selection of a nonionic surfactant is critical in the waste treatment process.

Surfactant costs—From the energy saving point of view, nonionic surfactants used in cloud-point extraction should have their Tcp of 20–50 °C so that the extraction occurs at an acceptable rate. Commercial nonionic surfactants are octylphenol or nonylphenol polyoxyethanol such as Triton X-110, Triton X-114, NPE_{9-10}, etc. These surfactants have their Tcp between 20–60 °C, and they are suitable for cloud-point extraction. For chromium(III) ion extraction, the temperature of choice was governed by the comparatively slow rate of complex formation with these so-called inert complexes. Several groups of surfactants are available, each with advantages and disadvantages.

For example, NPE_{9-10} (Igepal CO series, \$40.50/500g) is much cheaper than Triton X series (\$95.75/25g). For 1% NPE_{9-10} surfactant concentration, \$80.50/drum is invested. After the extraction, 0.18 mmole/L remains in the aqueous phase and cost is about \$0.90/drum. If Triton X100 were used, 0.25–0.99 mmol/L would remain in the aqueous phase, and the cost is unacceptably high (\$48.5-\$245/drum). Moreover, phenol-based surfactants are degraded into substituted phenols, RC_6H_4OH, which are toxic to many organisms, although widely used in industries and households. One way of minimizing the amount of phenol-based surfactant potentially released into the environment is to decrease the critical micelle concentration (CMC).

Non-phenol surfactants, such as polyethylexylate and Tween series can be used in large scale treatment. Those surfactants have low prices (Tween series: \$166.50/18L and Brij series: \$36.45/kg). In extraction process, only \$9.30/drum is invested for a 1% surfactant concentration. However, for Tween 40 and Tween 60, a large amount of surfactant would remain in the aqueous phase (27–29 mmol/L) at a cost is \$31.50–32.00/drum. For Tween 20, Tween 80, and Tween 85, a very low concentration (0.01–0.06 mmol/L) remains in the aqueous phase at a cost of \$0.02–0.07 cents/drum. The main problem with Tween surfactants is their high cloud-point temperatures.

Brij 56 (Tcp: 64–69 °C) was an ideal surfactant used in this extraction. Only \$36.45/drum would be invested and only 0.006 mmol/L would remain in the aqueous phase.

Cost of Chelating Agents——Selection of a chelating agent in cloud-point extraction of metal ions depends on the specific metal ion extracted For copper or a similarly fast- reacting metal ion, more hydrophobic chelating

TABLE 2. Related costs in treatment of chromium(VI) and Cu(II) waste

Item	Initial outlay	Lost to water	Recycling
Sugar	\$0.67	\$0.67	\$0.67
Surfactant	\$36.45	\$0.13 \$0.36	\$0.13
Chelator (8-hydroxyquinoline)	\$196.00	\$2.32 \$19.60	\$2.32
Other: 1 mole NaOH			
Energy costs	?		
Manpower: 1 man-hour	?		
Capital equipment	?		

* Calculations are based on 100 L of 1000 ppm chromium(VI).

agent LIX 54 could be used (Wang et al., 1996), but this was found (Wang et al., 1997) to be unsuitable for chromium(III). The cloud-point extraction procedure was like conventional liquid-liquid extraction in at least one respect: the formation rate of metal complex is a key factor in the selection of chelating agent. For co-extraction of copper and chromium(III), 8-hydroxyquinoline derivatives were suitable chelating agents (Wang et al., 1996, 1999a,b). Treatment of one drum (100 L) containing 1×10^{-2} *M* copper(II) ion and 2×10^{-2} *M* chromium(III) ion, 11 moles of chelating agent would be needed for a chelating agent/chromium(III) ion molar ratio of 4.5. The cost of 8-hydroxyquinoline, 2-methyl-8-hydroxy quinoline, and 2-chloro-8-hydroxyquinoline was \$196, \$221, and \$428, respectively, at Aldrich's 1998 retail prices.

Fortunately, the unreacted chelating agent is extractable and little was lost in the aqueous phase. Based on detailed studies (Wang et al., 1999b,c), 1.24×10^{-3} *M* of HQ would be expected to remain in the aqueous phase of the 100-L system. This is 18.3 g of chelating agent (cost is \$2.32). Only 2.07×10^{-4} *M* (3.3 g) of 2-methyl-8-hydroxyquinoline would remain (Wang, 1997) in the aqueous phase at a retail cost of \$0.43. For 5-chlorohydroxyquinoline (Wang, 1997), 0.23 g would be unextracted (1.3×10^{-5} *M* in 100 L), at a retail cost of \$0.05 cents per 100-L drum. Fortunately, the chelating agents are reusable, and recycling would save costs.

Reuse of chelating agent and surfactant—After cloud-point extraction, the majority of nonionic surfactant, metal complex, and unreacted chelating agent are present in the micellar phase. If this phase is treated with strong acid, metal ions are freed from metal complexes because no copper(II) and chromium(III) complexes are formed in solution at pH of 1 (Wang, 1997). When this acidic solution is subjected to cloud-point extraction, only chelating agent and nonionic surfactant are extracted into the micellar phase, and metal ions are left in the small-volume aqueous solution. The surfactant-rich phase containing chelating agent could be reused for cloud-point extraction of metal ions from the aqueous waste.

Other—The general costs for chemicals are summarized (Table 1) for the reagents that would be used. The costs would change little for the copper(II) ion present. It is assumed (Table 2) that substances in water could not be recovered (see recycling costs). It is also assumed that reagent costs would be reduced through recycling. Specifically, 90% recovery was assumed leading to a loss of 10% for the initial outlay. It is likely that this could be improved.

As noted above, other costs for energy, manpower, and capital outlay are uncertain, but economies of scale are likely. Omitting these costs, then cost of reagents per 100-L drum would be about $26, regardless of chelating agent chosen.

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CONCENTRATIONS OF TWO PHYTOTOXIC MATERIALS IN CATTAIL EXTRACTS: 2-CHLOROPHENOL AND SALICYLALDEHYDE

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Abstract: *Aqueous extracts of roots, stems and leaves of cattail,* Typha domingensis, *inhibited germination of lettuce seeds and caused inversion of some of the seedlings. The part of the plant found to be most phytotoxic in all the bioassays conducted in this study was the root, followed by the stem and the leaves. This correlated with the organic carbon (C_{org}) content of the three fractions. Previous studies of cattail extracts by gas chromatography/mass spectrometry had revealed the presence of 2-chlorophenol and salicylaldehyde (among other components). Bioassays using these two chemicals produced the same type of inhibition observed for the extracts. The relative concentrations of both components in the cattail extracts were determined using gas chromatography (external standard method) and were found to be in the order of milligrams per kilogram of fresh material. The chemicals were most concentrated in the root fraction, the concentration decreased in the stem and only small amounts of 2-chlorophenol were detected in the leaves. We believe that release of these and other phytotoxins enables cattails to hinder development of other species and plays a role in their aggressive colonization of water bodies.*

In the 1994 Florida Aquatic Plant Survey Report (Schardt, 1997), cattail species were found in more counties and in more water bodies than any other plant. Of the 389 waters surveyed, cattail was recorded as dominant in 203, which is 81 more waters than the second most dominant emergent species. In South Florida, *Typha domingensis,* the most common of the 3 cattail species found in the state (Long and Lakela, 1976), is believed to be a natural component of the Everglades ecosystem (Davis, 1994). In many cases, it has become the dominant marsh species, outcompeting native plants (Toth, 1988) and even clogging waterways. There are several factors contributing to the opportunistic expansion of cattails, including its size, fast growth habits, adaptability to changes in environmental conditions and water depth, and also a complicated chemical signaling mechanism that includes the release of chemical compounds that can have an effect on other organisms.

A number of studies over the years have focused on this process by which cattails inhibit growth and germination of other species and even their own seedlings. McNaughton (1968) found that aqueous extracts from *T. latifolia* leaves had a detrimental effect on the germination and growth of its own seedlings, and postulated that this autotoxic mechanism could account for the lack of cattail seedlings in undisturbed cattail stands. Van der Valk and Davis (1978), working with *T. glauca* litter, also found autotoxicity. However, Sharma and Gopel (1978) conducted similar experiments with other cattail species (*T. angustata* and *T. elephantina*) and failed to find inhibition of germination. Grace (1983) found that *T. latifolia* seeds sown into pots containing established mature plants germinated as well as seeds sown into control pots. Cattail toxicity towards other species has also been the subject of extensive studies with contradictory results. Szcepanska (1987) gives evidence of an allelopathic interaction between *T. latifolia* and several wetland species. Prindle and Martin (1996) report that aqueous extracts of *T. domingensis* inhibit the germination of lettuce and radish seeds and also reduce the oxygen production rates of the filamentous cyanobacterium *Lyngbya majuscula.* But Bonasera and co-workers (1979) and Elakovich and Wooten (1989) found a low inhibitory effect when testing *T. latifolia* extracts against several target species.

The inconsistencies noted between research groups could have multiple causes: the methods used were sufficiently dissimilar as to make comparisons difficult, several target species were studied at varying extract concentrations, and the cattail materials were collected at different times of the year. All these factors should be taken into consideration to correctly interpret the above mentioned studies. Changes in toxicity may be due to changes in the active toxin levels at different times of the year. Lohdi (1975) reported decreases in toxin levels in forest soils with fall quantities being significantly less than spring quantities. This highly variable temporal pattern has been noted by other authors, and it has been proposed as a possible explanation for transitory allelopathic potential (Gallet and Pellissier, 1997; Nilsson et al., 1998). A similar mechanism could account for the large variation in cattail phytotoxicity within studies. Controversy regarding the actual allelopathic effects has increased because of the difficulties in measuring the amounts of allelochemicals really available under field conditions.

Several phytotoxins have been isolated from *T. latifolia* organic extracts: Alliotta and co-workers (1990) found three steroids and three fatty acids with algicidal properties; Della Greca and co-workers (1990) isolated a 20S sterol with unusual configuration that showed activity against several blue-green algae in a paper disk bioassay. Several polyphenolic compounds such as 5-O-*trans*-caffeoylshikimic acid, epicatechin and afzelechin have been isolated in acetone extracts of *T. latifolia* flowers (Ozawa and Imagawa, 1988). However, the question of availability of these compounds in aquatic ecosystems remains open. Our group has been concerned with the isolation and quantification of phytotoxic compounds in aqueous cattail extracts, which should provide a better approximation of the actual bioavailability. In a previous study (Prindle and Martin, 1996), autoclaved *T. domingensis* extracts had phytotoxic properties, and the results obtained with them were not statistically different from the results with non-autoclaved material.

When studied using gas chromatography-mass spectrometry, two of the major components in the extract were 2-chlorophenol and salicylaldehyde (Prindle et al., 1996). These compounds were present in the *T. domingensis* growth front, but not in sediments two meters away from the cattail infestation (Albalat et al., 1997). A study of the inhibitory effect of the cattail extracts and these phytotoxins on the growth and production of chlorophyll by *Salvinia minima* has been reported elsewhere (Gallardo et al., 1998).

The present investigation was designed to elucidate the quantitative distribution of inhibitors in *T. domingensis* tissue and to further resolve the nature of the compounds causing inhibition from cattail, by testing their activity in a standardized bioassay. A knowledge of the chemistry of this sophisticated system will prove useful both in the management of undesired cattail populations and in the possible application of cattail-derived substances in the biological control of other aquatic species.

METHODS—In the present study, cattail extracts in water were prepared using roots, stems and leaves separately. The allelopathic potential of each fraction towards the germination of lettuce seeds was established, and the relative concentrations of 2-chlorophenol and salicylaldehyde in the cattail fractions were determined by means of gas chromatography studies using external standards.

Cattail extracts—Fully mature cattail samples were taken from a storm water ditch near the University of South Florida campus in Tampa, FL or from the North shore of Lake Behnke, at the USF Botanical Garden. The samples were identified as *T. domingensis* at the USF Herbarium. After collection, the samples were rinsed with deionized water and divided in three sections: the root system, the stem (taken from just above the root to the part where the leaves start separating) and the leaves. A portion (usually about 150 g fresh weight) of each section was weighed and extracted with deionized water (10 mL per 1.0 g of material) at room temperature using a Hamilton Beach blender. The resulting crude extracts were then filtered using Whatman no. 1 filter paper and the remaining liquid was then autoclaved for 1 h. (to sterilize it) and placed in a refrigerator at 0–4°C and disposed of after two weeks.

Determination of organic carbon–Organic carbon analyses of the cattail extracts were done using a Dohrmann (model DC-180) automated carbon analyzer. Aqueous extracts of sample root, stem, and leaves were analyzed for organic carbon content. Calibration was done using potassium hydrogen phthalate in deionized water, serially diluted from 2,000 ppm to give a 10 ppm working standard. The concentration of organic carbon was then calculated. Both 2-chlorophenol and salicylaldehyde were detected in the root and stem fractions, being more concentrated in the roots. Only 2-chlorophenol was detected in the leaves, which also proved to be the least active fraction. The results of the quantification were in accordance with the organic carbon content found for the three fractions, the root fraction having the highest organic carbon content, followed by the stems, and the leaves.

Phytotoxins—Known phytotoxic substances were also studied. Concentrations of 10, 20, 50, and 100 ppm of both 2-chlorophenol and salicylaldehyde in distilled water were tested. Under the conditions of the bioassay, the effective allelochemical concentrations were 2.5, 5.0, 12.5 and 25.0 ppm, due to the dilution factor. Reagent grade phenol was used to prepare a 10 ppm standard solution for comparison purposes.

Bioassays—Germination inhibition bioassays were performed using lettuce seeds (var. Black Seeded Simpson) (Fredonia Seeds, Chattanooga, TN). Lettuce seeds have been used for the detection of allelopathic compounds (Moon and Martin, 1981; Rice, 1984; Leather and Einhellig, 1986; Prindle and Martin, 1996) because of their availability, reproducibility, and high germination rates. The seeds were disinfected by rinsing in a 5% solution of commercial bleach for a minute, followed by 5% Alconox in water for a minute, and finally distilled water until no residual foam was observed. Then, 10 seeds were placed on each well of a 3-cm diameter well tray fitted with sterile disks of Whatman #1 filter paper. Aseptic conditions were maintained at all times. First, 1.5 mL of distilled water was dispensed into each well of the well tray with a sterile pipet; then 0.5 mL of the substance being tested (either a cattail extract, the phenol standard solution, or a solution of the allelochemicals) was added to the well. Each of the test substances was replicated twice, in a randomized design. The control wells received 0.5 mL of distilled water, and there were 3 control wells on each tray. The trays were then wrapped in clear plastic and kept under constant cool white light (170 μE/m^2/sec as measured by a LI-COR model LI-185A photometer). The trays were aerated, and the moisture replenished every other day. Every day, the number of germinated seeds and orientation of the seedlings was recorded.

The bioassays were repeated three times, always randomizing the position of the test solutions in the wells. After two weeks, the seedlings were measured and fresh weights were obtained for the material on each well. Representative samples were then air dried at room temperature for two days to obtain the dry weight.

Quantification of phytotoxins—For the purpose of quantifying the two allelopathic materials, aqueous cattail extracts were prepared in the same way mentioned before. Once filtered, the extracts were passed through solid-phase extraction cartridges with a C_{18} bonded phase (Bond Elut, Analytichem International, Harbor City, CA) previously conditioned by serial elution with 2 mL redistilled methanol and 4 mL distilled water. After passing the aqueous extract, the cartridge was eluted with 10 mL redistilled methanol, and the eluate was dried with anhydrous sodium sulfate and collected in a vial. The methanol was then evaporated under a nitrogen stream and the dry organic residue was redissolved in a known volume of redistilled dichloromethane. A 1 μL aliquot of the sample was taken for analysis by gas chromatography. A Perkin-Elmer Synch 2000 gas chromatograph with a LCI laboratory computing integrator was used with a flame ionization detector (FID). We used a Supelcowax (Supelco, Inc., Bellefonte, PA) fused silica capillary column (30 m x 0.53 mm i.d. with a 1.00 μm film thickness) and temperature programming from 50–200°C.

Standard solutions of 2-chlorophenol and salicylaldehyde in redistilled dichloromethane were prepared and injected separately under the same conditions. These solutions were used to make calibration curves for both chemicals and to determine their relative concentrations in the cattail extracts. Linear results were obtained in the range of 1–100 ppm (area as a function of concentration, $R^2 > 0.998$).

Data analysis—Statistical evaluation of the results was made by analysis of variance. All tests showed a significant level of variance between groups ($P < 0.01$). Treatment differences were tested at the 5% level using the least significant difference test.

RESULTS—Several types of behavior of lettuce seeds in the presence of allelopathic materials have been noted (Moon and Martin, 1981): type 1, normal, with the cotyledons and hypocotyl oriented in the proper manner and raised upward at least 1 cm by the hypocotyl from the filter paper, was the type of behavior observed in all the controls in our study. Coloration of these seedlings was normal, with green cotyledons and a white hypocotyl. When the aqueous extracts of the cattail fractions were used to imbibe lettuce seeds, inhibition of the germination process was obvious within 24 h. While the seeds in the control wells swelled and the sheaths broke open, the seeds in the presence of the cattail extracts remained undisturbed during this crit-

TABLE 1. Lettuce germination bioassay results using cattail extracts

Fraction	% Germination (168 h)*	Observation
Distilled water (control)	96.7 ± 2.9	normal (expected coloration and orientation)
2.5 ppm Phenol (standard)	75.0 ± 5.0	brown root tips, 100% inverted hypocotyls
Cattail root	41.6 ± 2.9	brown root tips, 100% inverted hypocotyls
Cattail stem	58.3 ± 2.9	brown root tips, 50% inverted hypocotyls
Cattail leaves	83.3 ± 5.8	brown root tips, 40% inverted hypocotyls

* Mean value ± standard deviation.

ical period and did not begin germination until 48 h later. Coupled with the severe inhibitory effect, a hindering of normal development was also observed: browning of the root tips and abnormal (inverted) cotyledon orientation were present in most of the seedlings exposed to the cattail fraction extracts. The inhibitory effects were most noticeable in the root fraction, where only 41.6 % overall germination was observed and all the seedlings were inverted. However, the stem and leaves extracts also inhibited growth and produced some inversion of the seedlings. The observed effects on seedlings correspond to type 4, inversion, which Moon and Martin (1981) described as a downward orientation of the cotyledons and a dark coloration of the emerging radical and lower hypocotyl. The cattail root and stem extracts were even more inhibitory than the 10 ppm phenol solution used as a standard (diluted to a 2.5 ppm effective concentration) (Prindle and Martin, 1996) (Table 1).

The organic carbon content of the extracts (Table 2) correlated with the observed inhibitory effects. In previous studies, Prindle and co-workers (1996) showed the presence of 2-chlorophenol and salicylaldehyde in aqueous cattail extracts. We quantified the relative amounts of these two components in the fractionated cattail extracts used in the bioassays. Gas chromatographic analysis of the extracts enabled us to determine their relative concentrations (Table 2). In accordance with their organic carbon content, the root fraction had the highest concentrations of both components, followed by the stem fraction and finally the leaves. The two phenolic compounds were found to be in the order of milligrams per kilogram of fresh material, and 2-chlorophenol was more abundant than salicylaldehyde in all cases. Salicylaldehyde was not detected in the leaves. Natural variation be-

TABLE 2. Concentrations of 2-chlorophenol and salicylaldehyde in cattail fractions

Cattail fraction	Total organic carbon (ppm)*	2-Chlorophenol (ppm)*	Salicylaldehyde (ppm)*
Root	616.5 ± 0.7	7.6 ± 0.8	2.1 ± 0.3
Stem	289.9 ± 1.7	7.4 ± 1.5	1.2 ± 0.2
Leaves	129.4 ± 1.3	4.5 ± 0.6	not detected

* n = 4; Mean value ± standard deviation.

TABLE 3. Lettuce germination bioassay results using 2-chlorophenol and salicylaldehyde

Effective concentration (ppm)	% Germination (168 h)*	Observation
2-chlorophenol		
2.5	58.3 ± 2.9	brown root tips, 50% inverted hypocotyls
5.0	65.0 ± 5.0	brown root tips, 80% inverted hypocotyls
12.5	46.7 ± 2.9	brown root tips, 100% inverted hypocotyls
25.0	18.3 ± 2.9	brown root tips, 100% inverted hypocotyls
Salicylaldehyde		
2.5	76.6 ± 2.9	brown root tips, 40% inverted hypocotyls
5.0	56.7 ± 5.8	brown root tips, 75% inverted hypocotyls
12.5	48.3 ± 2.9	brown root tips, 100% inverted hypocotyls
25.0	30.0 ± 5.0	brown root tips, 100% inverted hypocotyls

* Mean value ± standard deviation.

tween the plant samples may account for the large standard deviations observed. A seasonal variation in concentration may also be considered, since the samples were collected during spring and summer of 1996. Considering the concentrations of the two components determined in the root fraction, the amounts present under the conditions of the bioassay are approximately 4 ppm of 2-chlorophenol and 1 ppm of salicylaldehyde.

A working range for testing was estimated using these data, and effective concentrations from 2.5 to 25 ppm were tested. This corresponds to 10^{-4}-10^{-5}M final concentrations, which are the lowest recommended concentrations of allelochemicals used to assess phytotoxicity (Inderjit and Dakshini, 1995; Rice, 1984; Williams and Hoagland, 1982).

Aqueous solutions of both compounds at different concentrations were prepared and bioassayed against lettuce seeds. Results were similar to the cattail root fraction bioassay (Table 3), with inhibition and inversion of seedlings increasing as the concentration increased.

DISCUSSION—These results show that the allelopathic properties of cattails may be due to the presence of two (and possibly other) phenolic compounds. It has been suggested (Rice, 1984, Prindle and Martin, 1996) that phenolic allelopathic toxins affect the transfer of gibberellins through the seed membranes and that this may have an impact on the growth process. In addition to this effect, we also found a marked dehydration of the root tips, decrease of root pilosity and discoloration of the cotyledons, possibly due to the action of the phenolic compounds. A loss of membrane integrity and disruption of enzymatic pathways are also proposed modes of action for phenolic-type allelochemicals (Pandey, 1994; Einhellig, 1995). Our results are also in good agreement with this proposed action mode.

We have presumed that 2-chlorophenol was produced by the cattails, though an alternate possibility must be considered. It is possible that this substance was the result of bioaccumulation from an anthropogenic source. The latter possibility is plausible if there is no other source of this substance. Considering, however, that the number of known natural organohalogen compounds increased from 30 in 1968 to more than 2,400 in 1996 (Gribble, 1996), it is plausible that 2-chlorophenol is a natural product. Related compounds have been described: 4-phenyl-2-chlorophenol is present in *Anacystis marina* (Faulkner, 1980). Also, 2,5-dichlorophenol has been isolated from the common grasshopper (*Romalea microptera*); this phenol is repellant to ants and seems to be part of the defensive secretion, but it is believed to be of dietary origin (Eisner et al., 1971). A related possibility is that 2-chlorophenol results from the degradation of an anthroprogenic chlorophenol, e.g., 2,4-dichlorophenoxyacetic acid or a related herbicide, which has been used in Florida and elsewhere to control ditchweeeds and waterhyacinths. The matter needs further examination.

The quantification of allelopathic agents present in *T. domingensis* under actual conditions, as done in this study, provides an indication of potential elution. The additional roles that these agents have, and the extent of autoallelopathy was beyond the scope of the present study, and it must be considered later as part of a long-term study.

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AQUATIC TURTLES (TESTUDINES: EMYDIDAE) IN AN URBAN SOUTH FLORIDA MAN-MADE POND—*Wayne N. Witzell,* U. S.

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ABSTRACT: *Emydid turtles were surveyed in a man-made south Florida pond in 1993 and 1994. A total of 80* Pseudemys nelsoni, *70* Trachemys scripta elegans, *and 13* Pseudemys floridana peninsularis *were captured and marked. Mean carapace lengths and length to weight relationships for* P. nelsoni, T.s. elegans, *and* P.f. peninsularis *were described.*

SOUTH Florida has many man-made lakes and ponds. These are created by mining limestone for cement production and to provide waterfront properties for housing developments. Threading between these bodies of dredged water are canals designed to regulate water flow through south Florida, and are inhabited by a diverse assemblage of native and exotic fish (Loftus and Kushlan, 1987). Turtle research in south Florida, however, has been limited. Duellman and Schwartz (1958) described the south Florida ecological environment during Miami's initial urbanization, and were among the first researchers to initiate comprehensive studies on the life histories of south Florida amphibians and reptiles, including some emydid turtles. Subsequent studies of emydid turtles in South Florida have been limited to incidental observations on the nesting behavior of an emydid in alligator nests (Kushlan and Kushlan, 1980), and range extensions of emydids into the Florida Keys (Butterfield et al., 1994).

The importance of these aquatic habitats in Florida has not been adequately researched, and it is critical to document the life histories of aquatic organisms as south Florida continues to urbanize. The paucity of turtle studies is astonishing, considering the plethora of turtle species and active year-round abundance. This paper describes the results of a survey of emydid turtles in a small urban man-made pond in south Florida.

MATERIALS AND METHODS—The survey was conducted in a man-made pond located in a west-central Miami residential neighborhood, northwest of the intersection at SW 40 Street and SW 72 Avenue. The 2.9 ha pond was dredged in the early 1950s, and is approximately 3.2 m deep with a uniformly flat bottom. The pond is connected to a canal that extends west along State Road 41 to the Everglades, northeast along State Road 826 to the Miami International Airport lakes, and east through residential neighborhoods into the Coral Gables Waterway.

The turtle survey was conducted daily in April and May 1993 and 1994, when the turtles were actively courting. Turtles were attracted to the pond bank with dry cat food two hours before sunset and captured by dip net. The turtles were identified to species using a key modified after Carr (1952) and Ernst and Barbour (1972), weighed by spring scale, and individually marked by notching the marginal scutes (Cagle, 1939). Morphometric measurements were made with vernier calipers: carapace length (nuchal to tip of postcentral), maximum carapace width, and plastral length (gular notch to tip of anal). Adult sex was determined whenever possible by secondary sexual characters, which included elongated foreclaws and long, thick, muscular

TABLE 1. Mean straight-line carapace lengths (cm) of red-bellied turtles, red-eared sliders, and peninsular cooters.

Species	Mean length	sd	n
P. nelsoni			
Male	20.6	2.9	41
Female	23.1	8.5	36
Unknown	5.1	0.9	3
All	21.1	6.9	80
T.s. elegans			
Male	16.7	2.9	49
Female	22.0	2.2	18
Unknown	5.9	0.4	3
All	17.6	4.4	70
P. f. peninsularis			
Male	22.9	2.0	8
Female	28.9	2.1	5
Unknown	5.6	—	1
All	23.8	6.1	14

tails, and melanism in males (Ernst and Barbour, 1972). The general condition, presence of algae, parasites, and any abnormalities were also recorded and the turtles were immediately released.

RESULTS AND DISCUSSION—A total of 80 red-bellied turtles (*Pseudemys nelsoni*), 70 red-eared sliders, (*Trachemys scripta elegans*), and 13 peninsula cooters (*Pseudemys floridana peninsularis*) were captured during this study. Mean turtle lengths and length to weight relationships are in Tables 1 and 2, respectively. The length to weight relations were described as linear with female red-bellied turtles and red-eared sliders, and male peninsula cooters having the highest r^2 values. Mean turtle sizes were similar to those reported

TABLE 2. Length (cm) to weight (kg) relationships of red-bellied turtles, red-eared sliders, and peninsula cooters.

Species	Relationship	r^2	n
P. nelsoni			
Male	$W = -2.47 \pm 0.185\ CL$	0.88	40
Female	$W = -3.40 \pm 0.241\ CL$	0.91	32
All[1]	$W = -2.38 \pm 0.193\ CL$	0.83	76
T.s. elegans			
Male	$W = -1.23 \pm 0.118\ CL$	0.93	48
Female	$W = -3.09 \pm 0.220\ CL$	0.95	17
All[1]	$W = -1.38 \pm 0.134\ CL$	0.85	69
P. f. peninsularis			
Male	$W = -2.84 \pm 0.191\ CL$	0.94	7
Female	$W = 0.45 \pm 0.102\ CL$	0.71	4
All[1]	$W = -1.70 \pm 0.159\ CL$	0.79	13

[1] Includes immature turtles of unknown sex.

in Ernst and Barbour (1972), but there are no published studies to compare with the length to weight relationships. The expected sexual dimorphism of the adult turtles is most evident in the red-eared sliders and peninsula cooters, and the lack of smaller specimens is evident, particularly in peninsula turtles, and indicates that sampling may be biased towards large specimens.

The results of this survey indicate that there are thriving freshwater turtle populations in urban south Florida ponds and canals, and the population level of the introduced red-eared slider rivals the density of the native red-bellied turtle. The information presented here will hopefully assist aquatic scientists to effectively evaluate the status of these turtle populations in the future and mitigate conflicts due to continuing urban development.

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VEGETATION AND FLORA OF BRUNER'S SINK, A REMNANT BALD CYPRESS DOME IN CENTRAL FLORIDA

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ABSTRACT: *Bruner's Sink in Osceola County, Florida, is dominated by giant Bald cypress [*Taxodium distichum *(L.) Rich.] and Swamp Tupelo (*Nyssa biflora *Walter). The vascular flora numbers sixty species. This predominantly deciduous wetland forest of cypress and hardwoods over mucky calcareous soils represents a vanishing plant community type in Florida.*

ABOUT fifty years ago, H.A. Kurz and K.A. Wagner described cypress stands in the pineland west of Melbourne, Florida as "cypress domes" (Kurz and Wagner, 1953). These cypress domes are predictably dominated by Pond cypress (*Taxodium ascendens* Brongn.) and, although quite old, have slender, pole-like trunks. The trees become shorter toward the outer edges of the circular stand, forming a dome-shape. Cypress domes or sinks can still be seen across the karst landscape as one drives along Route US 192 from Melbourne to Kissimmee in central Florida.

An exception to these small-treed sinks here is a significant 10-acre cypress dome-shaped stand with giant Bald cypress [*T. distichum* (L.) Rich.] adjacent to Jane Green Swamp (Fig. 1). I named this stand for its owner, C.M. Bruner, who showed me these magnificent trees during graduate study of the Bull Creek Watershed twenty years ago (Huck, 1979). Cypress were found extensively throughout the Hopkins tract around the turn of the century (Johnston, *ca.* 1916), and these giant trees apparently missed the extensive timbering by the Union Cypress Company during that time (Figs. 1, 2). The objective of this paper is to update and report on the vegetation, vascular flora and soils of Bruner's Sink.

LOCATION—Bruner's Sink is found in the Bull Creek Watershed (Huck, 1987) at the Brevard-Osceola Counties line, at the juncture of two creeks, Bull and Crabgrass Creeks (Fig. 1). At the Pamlico Scarp (White, 1958), these creeks merge to form Jane Green Swamp, a tributary into the St. John's River floodplain (Fig. 1). From knolls of 50 feet (15.2 m) in the nearby pineland, elevation drops to 35 feet (10.7 m) at Bruner's Sink and, ultimately, to 25 feet (7.6 m) at Jane Green Swamp (U.S.G.S., 1972). Limestone lies approximately one hundred feet below the surface of the soil (Brown et al., 1962); sinks, sloughs and pond depressions result from dissolution of underlying limestone. Six major soil types and a high diversity of plant

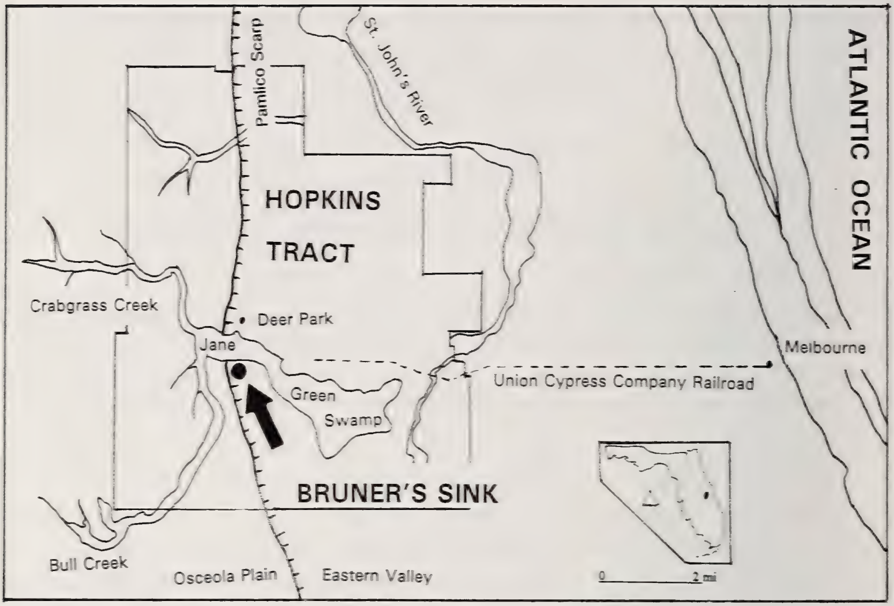

FIG. 1. Location of Bruner's Sink on Jane Green Creek, just west of Melbourne and south of Deer Park, Osceola County, Florida. At the turn of the 20th Century a railroad line (dotted line) carried timber, Yellow Pine and Cypress, from Deer Park to a mill south of Melbourne, Florida (Map based on Johnston, *ca.* 1916). Pamlico scarp lines and physiographic units are as delineated by White (1958; 1970).

communities were found in the Bull Creek Watershed (Huck, 1987). Precipitation is seasonal and the sink is flooded during the summer months.

METHODS—The flora was collected throughout the years 1977–78 as a part of a master's degree study at the University of North Carolina (Huck, 1979) and voucher specimens were deposited in NCU. The site has been protected for twenty years and the flora is substantially unchanged since the original inventory. Future investigations should include a complete study of the epiphytes, both vascular and non-vascular. Nomenclature has been updated to Wunderlin (1998), for the most part. The treatment of *Taxodium* follows Godfrey (1988) rather than Watson (1985) and Hart and Price (1990). Leaves of the Bald cypress here are slightly appressed to the branchlets, not linear and feathery, as stated by Godfrey (1988), but distinct from the awl-shaped, imbricate leaves of Pond cypress in pond depressions of nearby pinelands.

Canopy and subcanopy vegetation were analyzed by the quarter-point method in which Importance Value (IV) is the sum of relative frequency, relative density and relative dominance and D is the mean distance between trees (Mueller-Dombois and Ellenberg, 1974). Circumference measurements of the trees were made with a measuring tape at chest height. Tree height was assessed with a clinometer. Shrub and herb layers were sampled by the releve method according to Mueller-Dombois and Ellenberg (1974). Methods for soil sampling and analysis follow those of Huck (1987).

RESULTS—The vascular flora at Bruner's Sink numbers 60 species, including 16 ferns, one gymnosperm, and 43 angiosperms, including 11 mono-

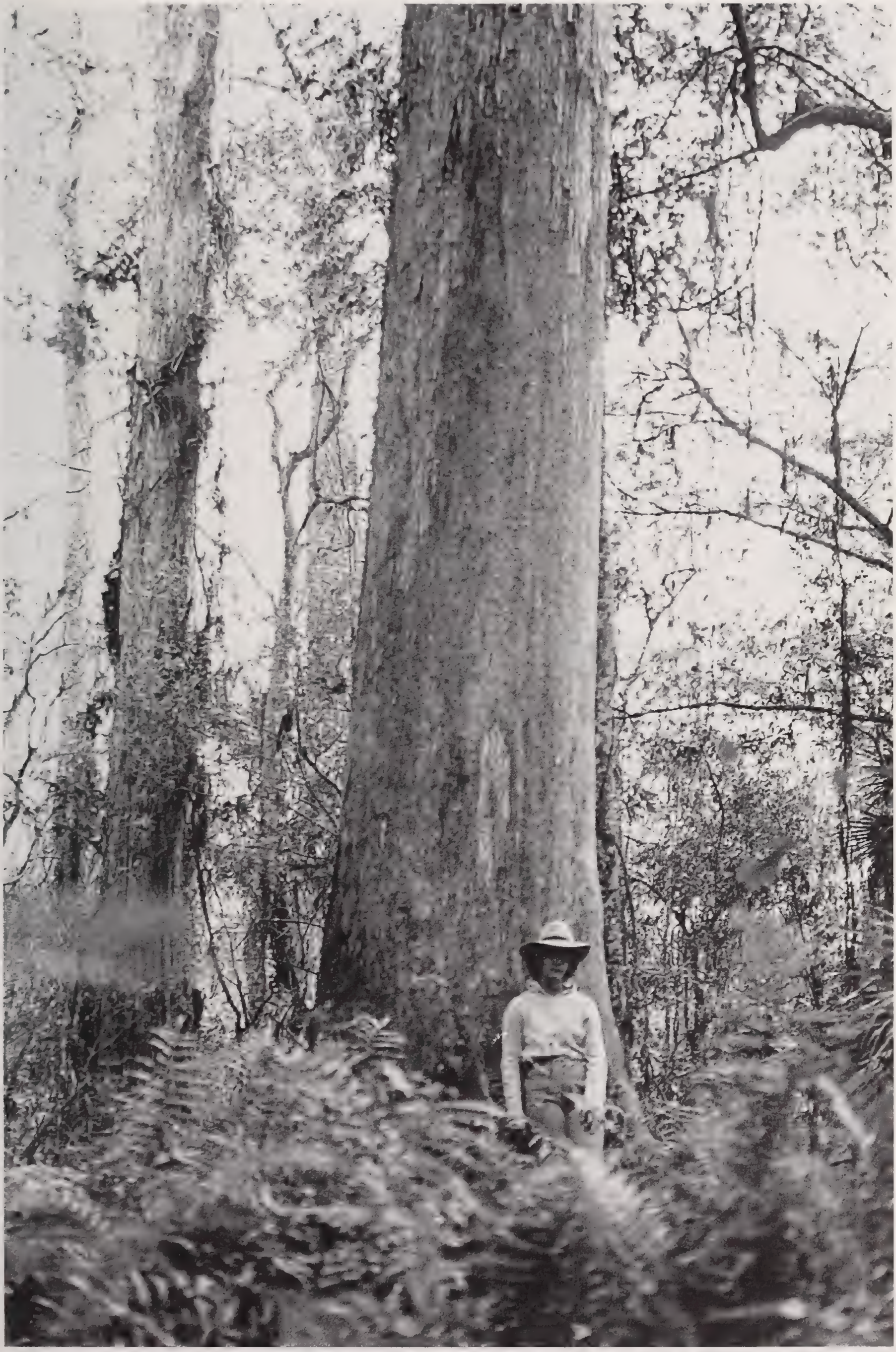

FIG. 2. Trees of Bald cypress in Bruner's Sink and fern-dominated herb layer. The person pictured is E.L. Huck, 5 ft (1.5 m) tall.

TABLE 1. Quarter method analysis of canopy and subcanopy of Bruner's Sink (IV = Importance Value; Rel Den = Relative Density; Rel Dom = Relative Dominance; Rel Freq = Relative Frequency; D = mean distance).

Species	IV	Rel Den	Rel Dom	Rel Freq
Canopy				
Taxodium distichum	270.60	87.50	88.90	94.20
Nyssa biflora	29.48	12.50	11.10	5.88
No. of Points: 4	D: 54.47 ft		No of trees/acre 14.6	
Subcanopy				
Magnolia virginiana	110.28	43.75	32.59	34.49
Acer rubrum	76.99	22.90	29.95	24.14
Nyssa biflora	28.73	8.33	13.51	6.89
Myrica cerifera	20.09	6.25	3.49	10.35
Sabal palmetto	19.89	4.16	8.84	6.89
Ulmus americana	15.27	6.25	5.57	3.45
Fraxinus caroliniana	7.66	2.08	2.13	3.45
Persea palustris	7.17	2.08	1.64	3.45
Quercus laurifolia	7.00	2.08	1.47	3.45
Ilex cassine	6.35	2.08	.82	3.45
No of Points: 12	D: 9.84 ft		No of trees/acre 449.86	

cotyledons and 32 dicotyledons (Appendix 1). Bald cypress and Swamp tupelo (*Nyssa biflora*) were the only two species present in the canopy and were widely spaced at a mean distance of 54.4 ft (16.6 m) from one another (Table 1). The average circumference for Bald cypress ranged from 102 in (260 cm) to 137 in (347 cm) in circumference and the largest tree was 214 in (543 cm) in circumference with a height of 99 ft (30 m). The largest Swamp tupelo was 136 in (345 cm) and 90 ft (27 m) tall. Ten species were present in the subcanopy with Sweetbay (*Magnolia virginiana*) and Southern red maple (*Acer rubrum*) dominant (Table 1). The largest Sweetbay was 87 in (221 cm) in circumference and 69 ft (21 m) tall and the largest Southern red maple was 113 in (287 cm) in circumference and 109 ft (32 m) tall. In shrub releves, Virginia willow (*Itea virginica*), Gallberry (*Myrica cerifera*), Buttonbush (*Cephalanthus occidentalis*), Poison Ivy (*Toxicodendron radicans*) and grape (*Vitis rotundifolia*) were common (Huck, 1979). In the herb layer, ferns dominated, particularly Swamp fern (*Blechnum serrulatum*), Southern wood fern (*Dryopteris ludoviciana*), Cinnamon fern (*Osmunda cinnamomea*) and Royal fern (*Osmunda regalis*) (Huck, 1979).

Soils of Bruner's Sink were mollisols, mucky calcareous soils (Table 2). Calcium ranged from 874–4144 ppm, magnesium from 16–1552 ppm, and organic matter was 0.8–25.3 % in that soil, with the highest quantities of muck in the upper layers of the soil (Table 2). The upper horizon of the soil overlies a clay horizon which supports a perched water table. By comparison, cypress domes dominated by Pond cypress in the flatwoods have mucky acid soil, or sandy, wet soils and generally lower concentations of nutrients (Table 2).

TABLE 2. Comparison of soil characteristics, pH, and percent organic matter for Bald cypress in Bruner's Sink and Pond cypress in pinelands (ppm = parts per million; Ca = calcium; Mg = magnesium; Org Mat = organic matter).

Community cover	Soil family	Ca, ppm	Mg, ppm	pH	Org Mat, %
BALD CYPRESS—BRUNERS SINK					
Cypress dome	Mollisol				
	Horizon A1	4,144	1,552	5.4	25.3
	B21t	1,094	57	6.7	6.7
	B22T	874	16	7.3	.8
POND CYPRESS—PINELANDS					
Cypress domes and sinks	Histosols and Inceptisols	480–2,965	25–36	4.0–5.2	4.5–62.5

Discussion and Conclusions—Bruner's Sink is a predominately deciduous wetland forest of cypress and hardwoods. The deciduous aspect of the autumnal russet-brown leaves of Bald cypress and maroon-red leaves of the Swamp tupelo and Southern red maple is followed by stark gray trunks with numerous Tillandsias visible in winter and then by the green haze of spring as new leaves emerge. This view contrasts with northern Florida swamps where subtropical epiphytic elements are missing and evergreen wetland shrubs and trees such as Black titi (*Cliftonia monophylla*), Dog-hobble (*Leucothoe axillaris*), Overcup oak (*Quercus lyrata*) and Laurel oak (*Q. laurifolia*) are common (see Ewel, 1990). The huge trees at Bruner's Sink tower above nearby trees in the landscape and their enormity is appreciated as one moves around the "knees" within the dome. There is a general openness on the forest floor due to the sparse shrub layer, however, the herb layer, dominated by ferns is very dense (Fig. 2).

When scored by the American Forests formula for State Champion Trees the largest Bald cypress at Bruner's was the eleventh largest in the State of Florida (330 points) with a status of Honorable Mention; Swamp tupelo was the third largest in the State (241 points) with a status of Honorable Mention; Southern red maple was fifth (237 points) with a status of Florida Challenger; and Sweet Bay was the second largest in the State (166 points) with a status of Florida Challenger (Ward, 1998). Although the sizes of the cypresses do not approach the 425 in (1,079.5 cm) circumference of the Florida state champion, "The Senator", at Longwood, Florida (see Ward and Ing 1997), the trees here are notable for their size and numbers present and the stability of the plant community.

Although low in species diversity, as is typical of river cypress swamps (Ewel, 1990), Bruner's Sink has distinctive floristic elements. Subtropical Strap fern (*Campyloneurum phyllitidis*), Shoestring fern (*Vittaria lineata*), Wild Coffee (*Psychotria nervosa*) and Myrsine (*Rapanea punctata*) are near their northern range here. Wild pine (*Tillandsia simulata*) is a Florida endemic (Wunderlin, 1998) and Needle palm (*Rhapidophyllum hystrix*) is an important endemic of the southeastern United States (Small 1923). There are a few non-native species: Macrothelypteris (*Macrothelypteris torresiana*), Downy shield fern (*Thelypteris dentata*), Elephant ear (*Xanthosoma sagittifolium*) and Caesar-weed (*Urena lobata*). One notices that many of the herbs such as ferns, poison ivy (*Toxicodendron radicans*) and Lizard's tail (*Saururus cernuus*) are toxic or aromatic, perhaps as a result of adverse selection against other herbs by rooting feral pigs which, in the past, have entered the cypress dome.

Bruner's Sink occurs at the dynamic interface of two physiographic units (*sensu* White, 1970): the Osceola Plain with an extensive flatwoods system and the Eastern Valley of the St. John's River floodplain (Fig. 1). The spodic, base-deficient soils of the extensive pinelands contrast with the lower, rich alluvium of creeks and swamps of the Bull Creek Watershed in which this Sink is found (Huck, 1987). Deposition of mucky calcareous soils into those creeks and swamps apparently occurred with the leaching of the flatwoods. The presence of these basic soils, mollisols, is curiously rare in Central Florida but extensive in the prairie soils of the mid-western states in glaciated areas where drift and loess are calcareous (Soil Survey Staff, 1975). Nutrient-rich soils and available fresh water of nearby Jane Green Swamp suggest more favorable growing conditions for Bald cypress than for Pond Cypress in isolated, acidic ponds throughout the fire-maintained flatwoods.

Bruner's Sink has a high degree of integrity and represents a remnant of a vanishing community type in Florida. As most published studies on cypress swamps in Florida have been undertaken in northern and southern localities of the State, inventory of this dome extends an understanding of cypress ecosystems in central Florida. This site is a small ecological gem, significant for the scenic grandeur of its huge trees.

Acknowledgments—Bruner's Sink is presently in private ownership. This paper is dedicated to C.M. Bruner and A. E. Radford of the University of North Carolina, lovers of big trees. Mr. Bruner died in 1988. I thank R. Peet of the University of North Carolina for visiting the site with me. I thank D.B. Ward for helping me update this paper with his insights on champion trees and for general comments on this paper. I am grateful to my daughter, E. L. Huck, for helping me with my original research and Mr. Bruner's grandson, M.D. Bruner, for assisting in recent updates of dimensions of trees. I thank W.O. White for soil determinations. I express my gratitude to K. Perkins, Collections Manager and N.H. Williams, Keeper of the Herbarium, University of Florida, for their generosity and support.

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APPENDIX 1. Vascular flora of Bruner's Sink, Osceola County, Florida.

PTERIDOPHYTES	
OSMUNDACEAE	
Osmunda cinnamomea L.	Cinnamon fern
O. regalis L. var. *spectabilis* (Willd.) A. Gray	Royal fern
PTERIDACEAE	
Pteridium aquilinum (L.) Kuhn var. *pseudocaudatum* (Clute) A. Heller	Bracken fern
POLYPODIACEAE	
Polypodium polypodioides (L.) Watt. var. *michauxianum* Weath.	Resurrection fern
Campyloneurum phyllitidis (L.) C. Presl.	Strap fern
VITTARIACEAE	
Vittaria lineata (L.) Sm.	Shoestring fern
BLECHNACEAE	
Blechnum serrulatum Rich.	Swamp fern
Woodwardia areolata (L.) T. Moore	Netted chain fern
THELYPTERIDACEAE	
**Macrothelypteris torresiana* (Gaud.) Ching	Macrothelypteris
Thelypteris palustris Schott	Marsh fern
Thelypteris kunthii (Desv.) C. V. Morton	Southern shield fern
Thelypteris interrupta (Willd.) Iwatsuki	Hottentot fern
**Thelypteris dentata* (Forssk.) E. St. John	Downy shield fern
Thelypteris hispidula (Decne.) C.F. Reed	Thelypteris
DRYOPTERIDACEAE	
Dryopteris ludoviciana (Kunze) Small	Southern wood fern
NEPHROLEPIDACEAE	
Nephrolepis exaltata (L.) Schott	Boston fern
GYMNOSPERMS	
CUPRESSACEAE	
Taxodium distichum (L.) Rich.	Bald cypress

Appendix 1. Continued.

ANGIOSPERMS	
CYPERACEAE	
Cyperus tetragonus Elliott	Sedge
BROMELIACEAE	
Tillandsia setacea Sw.	Wild pine
Tillandsia simulata Small	Wild pine
Tillandsia usneoides (L.) L.	Spanish moss
PALMAE	
Rhapidophyllum hystrix (Pursh) Wendl. & Drude ex Drude	Needle palm
Sabal palmetto (Walt.) Lodd. ex Schult. & Schult.	Sabal palm
ARACEAE	
Arisaema triphyllum (L.) Schott	Jack-in-the-pulpit
**Xanthosoma sagittifolium* (L.) Schott	Elephant ear
SMILACEAE	
Smilax bona-nox L.	Greenbrier
Smilax laurifolia L.	Bamboo vine
ORCHIDACEAE	
Erythrodes querceticola (Lindl.) Ames	Jug orchid
SAURURACEAE	
Saururus cernuus L.	Lizard's tail
MYRICACEAE	
Myrica cerifera L.	Wax myrtle
FAGACEAE	
Quercus laurifolia Michx.	Laurel oak
ULMACEAE	
Ulmus americana L.	Florida elm
MORACEAE	
Morus rubra L.	Red mulberry
MAGNOLIACEAE	
Magnolia grandiflora L.	Southern magnolia
Magnolia virginiana L.	Sweetbay
LAURACEAE	
Persea palustris (Raf.) Sarg.	Swamp bay
ESCALLONIACEAE	
Itea virginica L.	Virginia willow
ROSACEAE	
Rubus argutus Link	Highbush blackberry
Prunus caroliniana (Mill.) Aiton	Cherry laurel
LEGUMINOSAE	
Apios americana Medicus.	Groundnut
ANACARDIACEAE	
Toxicodendron radicans (L.) Kuntze	Poison ivy
AQUIFOLIACEAE	
Ilex cassine L.	Dahoon holly
ACERACEAE	
Acer rubrum L.	Southern red maple

APPENDIX 1. Continued.

VITACEAE	
Ampelopsis arborea (L.) Koehne	Pepper vine
Vitis rotundifolia Michx.	Grape
Vitis shuttleworthii House	Calusa grape
Parthenocissus quinquefolia (L.) Planch.	Virginia creeper
MALVACEAE	
**Urena lobata* L.	Caesar-weed
NYSSACEAE	
Nyssa biflora Walter	Swamp tupelo
OLEACEAE	
Fraxinus caroliniana Miller	Pop ash
MYRSINACEAE	
Rapanea punctata (Lam.) Lundell	Myrsine
LOGANIACEAE	
Gelsemium sempervirens (L.) W.T. Aiton	Yellow jasmine
ASCLEPIADACEAE	
Matelea gonocarpos (Walter) Shinners	Matelea
VERBENACEAE	
Callicarpa americana L.	Beautyberry
SCROPHULARIACEAE	
Gratiola virginiana L.	Gratiola
BIGNONIACEAE	
Campsis radicans (L.) Seemann ex Bureau	Trumpet-vine
RUBIACEAE	
Cephalanthus occidentalis L.	Buttonbush
Psychotria nervosa Sw.	Wild coffee
CAPRIFOLIACEAE	
Sambucus canadensis L.	Elderberry
CUCURBITACEAE	
Melothria pendula L.	Creeping cucumber

* Non-native plants.

NOTES ON TREE ROOST CHARACTERISTICS OF THE NORTHERN YELLOW BAT (*LASIURUS INTERMEDIUS*), THE SEMINOLE BAT (*L. SEMINOLUS*), THE EVENING BAT (*NYCTICEIUS HUMERALIS*), AND THE EASTERN PIPISTRELLE (*PIPISTRELLUS SUBFLAVUS*)

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ABSTRACT: *We radio-tracked one northern yellow bat (*Lasiurus intermedius*), three Seminole bats (*L. seminolus*), three evening bats (*Nycticeius humeralis*), and one eastern pipistrelle (*Pipistrellus subflavus*) to locate and characterize their tree roosts. The northern yellow bat roosted in Spanish moss (*Tillandsia usneoides*) in live oaks (*Quercus virginiana*), located in a oak-hammock community. The Seminole bats roosted in slash pines (*Pinus elliottii*), loblolly pines (*P. taeda*), live oaks, and pond pine (*P. serotina*). Thirty-two of these 34 roost trees were in pine-dominated communities. Evening bats roosted in slash pines, loblolly pines, and live oaks. Thirteen of 14 roost trees were located in loblolly-slash pine communities. The eastern pipistrelle roosted in a community dominated by live oaks. Each eastern pipistrelle roost was located in Spanish moss in understory trees on exposed high-marsh hammocks. Our results support previous studies documenting the tree roosting habits of the northern yellow bat, evening bat, and eastern pipistrelle. We could find no records documenting strong roosting associations of Seminole bats with pines. Our findings suggest that during the period of parturition and lactation, Seminole bats commonly roost in pines.*

TWELVE species of bats are known to occur in coastal regions of South Carolina, Georgia, and northern Florida (Hall, 1981). All are known to use trees wholly or in part as roost sites; however, little information is available regarding roosting behavior of bats in these coastal ecosystems (Neuhauser and Baker, 1974). Harper (1927), Moore (1949), Pournelle and Barrington (1953), Ivey (1959), Golley (1962, 1966), Neuhauser and Baker (1974), and Schacher and Pelton (1979) provided comments on roosting behavior of several species, but these are descriptive rather than quantitative and drawn primarily from knowledge of roosting behavior elsewhere in the species' range. Constantine (1958), Jennings (1958), and Zinn (1977) have provided substantive discussions of roosting behavior of several species of bats elsewhere in the southeastern Coastal Plain of Georgia and Florida.

The resolution of issues concerning the impact of extensive commercial, residential, and silvicultural development of southeastern coastal ecosystems on maintenance of biological diversity requires quantitative information on various habitat use by mammalian species. As part of a vertebrate inventory of Sapelo Island, McIntosh Co., Georgia, we undertook studies relating to roost-site selection and use of habitat by bats. We report the results of radiotelemetric studies of roosting characteristics of four species of bats common to the island: northern yellow bat (*Lasiurus intermedius*), Seminole bat (*L. seminolus*), evening bat (*Nycticeius humeralis*), and the eastern pipistrelle (*Pipistrellus subflavus*).

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METHODS—The study was conducted on Sapelo Island from 19 June to 24 July 1995. Sapelo Island, the third largest of the Georgia Sea Islands, is approximately 16 km long and 3.2 km wide. It is located approximately 63 km south of Savannah and 5.5 km off the Georgia coast (31°27′N, 81°16′W). The north end of the island is dominated by the 4050 ha R. J. Reynolds Wildlife Refuge. Four, well-defined habitat types were available for roosting on the south end of the island: mixed oak-pine stands, oak stands dominated by live oaks (*Quercus virginiana*), communities dominated by pond pine (*Pinus serotina*), and loblolly-slash pine communities (*P. taeda* and *P. elliottii*). Spatially-explicit habitat maps exist for much of the island.

Sapelo Island is characterized by a subtropical, maritime climate with long, warm summers and short mild winters. Freezing temperatures do occur, but are few in the winter months. Average temperatures for June and July are 26.3 and 27.7 °C, respectively. Average monthly rainfall for June and July is 14.58 and 15.65 cm, respectively. The weather is seasonal with over half of the yearly precipitation occurring during the warm summer months and early fall months of June through September (Johnson et al., 1974; National Climatic Center, 1983).

Bats were captured in 2.8 × 12-m Japanese mist nets set over or near water. Netting was conducted throughout the study period (19 June–24 July). Nets were checked once an hour. Measurements taken on all captured bats included species, sex, age, forearm length, and weight. After measurements were taken, bats were banded with individually labeled, lipped wing bands (Greenhall and Paradiso, 1968). Bats were separated into juvenile and adult age classes by back-lighting finger joints and examining the level of epiphyseal-diaphyseal fusion (Anthony, 1988). Body mass was determined using a Pesola® spring scale.

We used eight, 0.46-g LB-2 transmitters (150–151 MHz; 10 day battery life) from Holohil Systems Limited (Ontario, Canada) to track Seminole bats (n = 3), evening bats (n = 3), a northern yellow bat (n = 1) and an eastern pipistrelle (n = 1). The transmitters had an effective range of 0.8 km and were attached to the back of bats with Skin-bond® brand surgical adhesive (Pfizer Hospital Products Group, Inc., Largo, Florida). Fur was not clipped prior to attachment of the transmitter. Transmitter load for the eastern pipistrelle and evening bats were 6.3% and 6.6% of body mass respectively; transmitter loads for the Seminole bats and northern yellow bat were less than 5%. These transmitter loads are consistent with those reported elsewhere (Bradbury et al., 1979; Stebbings, 1982; Brigham, 1989; Best and Hudson, 1996).

Each bat was located daily using Advanced Telemetry System (Isanti, Minnesota) R2000 receivers and 3-element Yagi antennas. After the roost tree was located, actual roost location was identified by watching the tree for emerging bats at dusk. The universal transverse mercator (UTM) coordinates of all roost trees were obtained using a Trimble Pathfinder Basic Global Positioning System® (GPS). The UTM coordinates of all roost trees located for each individual bat were overlaid on vegetation maps using an Arc Info® Geographic Information System (GIS). The habitat type surrounding each roost tree was recorded.

Vegetation surveys were conducted in a 0.04-ha circular plot surrounding each roost tree. The characteristics of the vegetation surrounding each roost were quantitatively measured. All trees with a diameter greater than 9 cm at breast height were placed in the overstory class. Tree species, height, diameter at breast height (DBH), and presence or absence of Spanish moss were recorded on all overstory trees within the plot. Canopy density was measured using a spherical densiometer. All trees with a DBH between 1 and 9 cm were placed in the understory

TABLE 1. Roosting habitat use by *Lasiurus intermedius, L. seminolus, Nycticeius humeralis,* and *Pipistrellus subflavus* on Sapelo Island, Georgia, 1995 (n = number of roost trees).

Roost habitat type	*L. intermedius* (n = 5)	*L. seminolus* (n = 34)	*N. humeralis* (n = 14)	*P. subflavus* (n = 11)
Loblolly-slash pine	0	22	13	0
Pond pine	0	1	0	0
Oak-pine	0	8	1	1
Oak	5	3	0	10

class. Species and number of understory trees, and the presence of saw palmetto (*Serenoa repens*) were recorded. The aspect and substrate (e.g., bark, foliage, cavity) of the roost, distance of the roost from the bole of the tree, and height of the roost were also measured.

To detect tertiary (within stand) roosting site selectivity (Johnson, 1980), four randomly selected, 0.04-ha, vegetation samples were taken in each of the four roosting habitats on the island. Species diversity, evenness, and richness in both the overstory and understory were calculated for the plots surrounding the roosts and the random vegetation plots. Shannon's diversity index and Pielou's measure of evenness were used in later analyses (Pielou, 1966). Measures of basal area were used in calculating all overstory indices. Understory calculations were based on number of stems per 0.04-ha circular plot.

The characteristics of the sample plots surrounding the roosts of Seminole bats and evening bats were compared to random samples taken from within the same habitat type using a one-way analysis-of-variance (ANOVA). We tested for difference in means using Tukey's multiple range test (SAS Institute Inc., 1990).

RESULTS AND DISCUSSION—We captured 2 northern yellow bats, 40 Seminole bats, 154 evening bats, 4 eastern pipistrelles, and 4 big brown bats (*Eptesicus fuscus*) during our survey. We tracked a northern yellow bat to five roost trees, three Seminole bats to 34 roost trees, three evening bats to 14 roost trees, and an eastern pipistrelle to 11 roost trees. Thirty-five roosts were located in loblolly-slash pine communities, ten were located in oak-pine communities, 18 were located in live oak communities, and one was located in a community dominated by pond pines (Table 1).

For the single male northern yellow bat, all roosts were in live oak-dominated habitat types characteristic of those described by Laessle and Monk (1961, Table 1). All roosts were located in Spanish moss hanging from the branches of large live oaks (Table 2). Constantine (1958), Jennings (1958), and Barbour and Davis (1969) reported northern yellow bats roosting in similar situations. Many roosts of the northern yellow bat have been found in palm fronds (Davis, 1970; Spencer et al., 1988). Although cabbage palms (*Sabal palmetto*) are common on Sapelo Island (Duncan, 1982), the yellow bat we tracked never roosted in that species. Webster and co-workers (1980) noted that roosts of the northern yellow bat typically are located near water. Roosts of the northern yellow bat on Sapelo Island were an average of 304 ± 29 m from one of the few permanent freshwater ponds on the island. Roosts of the northern yellow bat were always at heights >10 m and most commonly in the southwestern canopy quadrant.

One adult male, one lactating female, and one juvenile female Seminole

TABLE 2. Mean values of 15 roost characteristics of *Lasiurus intermedius, L. seminolus, Nycticeius humeralis,* and *Pipistrellus subflavus,* on Sapelo Island, Georgia, 1995 (± SE).

Roost characteristic	*L. intermedius* (n = 5)	*L. seminolus* (n = 34)	*N. humeralis* (n = 14)	*P. subflavus* (n = 11)
Richness of understory	6.60 (0.93)	2.97 (0.36)	2.00 (0.63)	3.33 (0.69)
Diversity of understory	1.55 (0.23)	0.61 (0.08)	0.51 (0.15)	0.45 (0.16)
Evenness of understory	0.85 (0.08)	0.63 (0.04)	0.74 (0.07)	0.39 (0.07)
Richness of overstory	4.60 (0.63)	3.15 (0.24)	2.36 (0.43)	4.33 (0.47)
Diversity of overstory	0.91 (0.18)	0.54 (0.07)	0.63 (0.12)	0.69 (0.14)
Evenness of overstory	0.57 (0.11)	0.47 (0.04)	0.80 (0.08)	0.46 (0.08)
Diam. of roost tree (cm)	95 (8)	44 (3)	42 (5)	30 (6)
Height of roost tree (m)	27.1 (3.0)	27.9 (1.2)	18.7 (2.1)	9.5 (2.3)
Height of roost (m)	10.7 (1.9)	16.3 (0.7)	8.2 (1.3)	4.9 (1.4)
Density of canopy (%)	92 (7)	69 (3)	67 (5)	86 (5)
Density of understory (%)	39 (19)	46 (7)	9 (13)	58 (14)
Basal area (m^2)	2.39 (0.20)	1.63 (0.78)	1.40 (0.14)	1.78 (0.15)
Moss density[a]	88 (6)	8 (2)	9 (4)	68 (5)
Height of canopy[b]	17.2 (1.7)	21.2 (0.7)	21.4 (1.2)	11.7 (1.3)
Mode aspect of roost	SW	SW	SW	NE

[a] The percent of overstory trees within the circular plot containing Spanish moss.
[b] Average height of all overstory trees within the roost vegetation plot.

bat were tracked. Thirty-four roost trees were located. Roosts of the Seminole bats were located in all four of the habitat types (Table 1). Thirty-two of the 34 roosts were located in pine trees. At these roosts, bats hung from small branches in or near the clump of needles at the tips of the limbs in the lower sections of the canopy. Bats were nearly indistinguishable from pine cones during ground observation efforts. Roosts were located in tall trees with large diameters (Table 2). Twenty roosts were located in slash pines, 11 in loblolly pines, two in live oaks, and one in a pond pine. Post oaks (*Quercus stellata*), laurel oaks (*Q. hemispherica*), and sand live oaks (*Q. geminata*) were common components of the overstory surrounding the roosts of Seminole bats. Similar to Constantine (1958), we found that Seminole bats most commonly roosted in the southwestern canopy quadrant.

Data on the vegetation surrounding roost trees in the two habitat types used most by Seminole bats were compared with data from random plots within the same habitat types. Samples surrounding the roosts more closely resembled random samples taken from loblolly-slash pine communities than from oak-pine habitats (Table 3). The overstory composition surrounding random plots from oak-pine communities was more even than the overstory composition surrounding roost trees. The overstory within oak-pine habitats typically is composed of an even mixture of oaks and pines. Within this habitat type, the roosts of Seminole bats were located in areas dominated by pines. Because pines tended to be taller than hardwoods in oak-pine communities on Sapelo Island, the average height of trees in the overstory was significantly higher in plots surrounding roosts than in randomly sampled plots. Within both loblolly-slash pine communities and oak-pine habitats, Seminole bats roosted in areas with higher than average basal areas (Table 3).

We found roosts of the Seminole bat to be unlike those previously described in the literature. Seminole bats have been found roosting in clumps of foliage (Sealander and Heidt, 1990), under loose bark (Sealander, 1979), and on the branches of trees (Barkalow and Adams, 1955), but are most commonly reported roosting in Spanish moss (Barbour and Davis, 1969; Constantine, 1958; Harper, 1927; Jennnings, 1958; Wilkins, 1987). While numerous records of Seminole bats foraging in pine-oak flatwoods exist (Harper, 1927; Ivey, 1959; Jennings, 1958; Moore, 1949; Zinn, 1977), we found none documenting strong roosting associations with pine-dominated communities. We know of no reports documenting a Seminole bat roosting in pines. Jennings (1958) reported that Seminole bats were commonly collected from Spanish moss throughout much of the year, but not in June and July. Constantine (1958) searched for Seminole bats in Spanish moss from February through June. May and June were the only two months his searches were unsuccessful. Roost selection for many species of bats show predictable temporal shifts (Fujita and Kunz, 1984; Humphrey, 1975; Jennings, 1958). Differences between the characteristics of roosts previously reported and the roosts we found are most likely attributable to the time period during which our study took place. We suggest that during the period of parturition and lactation, Seminole bats roost in the canopies of pines in pine dominated communities. Data from previous studies suggest Seminole bats primarily roost in Spanish moss during the winter. Increased parasite loads in Spanish moss during the summer may cause Seminole bats to avoid Spanish moss and roost in pines. Alternatively, it could be that Seminole bats roost in Spanish moss during the winter because of its insulatory properties. During the summer, because the insulatory properties of Spanish moss would no longer be an advantage, Seminole bats may begin roosting in pine foliage.

We tracked one adult male and two adult, non-lactating, female evening bats to 14 roost trees. Thirteen of the roosts were located in loblolly-slash pine communities; one was in an oak-pine community (Table 1). Cavities in ramicorn branches commonly were used as roost sites. Bark peeling from the bole of pine snags was also used. Roosts were located at an average height of 8.2 ± 1.3 m (Table 2). Roosts were located in three slash pines, four loblolly pines, and seven live oaks. The overstory surrounding the roosts of evening bats typically consisted of a loblolly or slash pine plantation. The understory was typically open and grassy. Eight of the 13 roosts were located on the southwestern side of the roost tree. The remaining five roosts were relatively evenly distributed in the northern and southeastern sides of the canopies of the roost trees.

When compared to random samples taken from loblolly-slash pine communities, the overstory surrounding roost trees was more uniform in composition than the overstory of plots sampled randomly (Table 3). The loblolly-slash pine communities on Sapelo Island are managed with differing

TABLE 3. Mean value of three roost characteristics of *Lasiurus seminolus* and *Nycticeius humeralis* compared to the characteristics of random sample plots established in the same community type (± SE).

	L. seminolus (Lob-slash)		*L. seminolus* (Oak-pine)		*N. humeralis* (Lob-slash)	
Roost characteristic	Roost	Random	Roost	Random	Roost	Random
Evenness of overstory	0.37 (0.07)	0.63 (0.20)	0.61 (0.06)	0.86 (0.08)*	0.80 (0.03)	0.63 (0.06)*
Basal area (m^2)	1.70 (0.10)	1.00 (0.30)*	1.60 (0.10)	0.83 (0.14)*	1.40 (0.09)	1.00 (0.16)*
Height of canopy (m)	21.3 (0.9)	21.4 (2.1)	21.2 (1.6)	12.7 (2.2)*	20.9 (0.9)	21.4 (1.6)

Asterisks indicated significant differences (* $P < 0.05$).

levels of intensity. Stands which are managed less intensively typically contain a large component of mixed hardwoods in the overstory. The overstory surrounding roosts of evening bats was more even than the overstory of random plots because evening bats roosted in areas of intensive pine silviculture. Accordingly, these areas lacked any substantial hardwood component. Evening bats roosted in forest patches with larger basal areas than random plots (Table 3). While loblolly-slash pine stands in all successional stages are located throughout the island, snags and ramicorn branches are most common to mature stands of pines. As a result, the basal areas of plots surrounding the roosts of evening bats were significantly greater than those of randomly sampled plots.

Roosts of the evening bat have been reported in cavities (Barbour and Davis, 1969; Harper, 1927) and under loose pieces of bark (Bailey, 1933; Barbour and Davis, 1969; Jennings, 1958). On Sapelo Island, evening bats roosted individually under bark and as small groups in cavities of trees. Cavities in dead ramicorn branches of pine trees were used. Spanish moss is common on Sapelo Island and evening bats have been reported to roost in this substrate (Jennings, 1958); however, we located no Spanish moss evening bat roosts.

We tracked one adult female eastern pipistrelle to 11 roost trees. Ten roost trees were located in a live oak community on a high-marsh hammock; one was located in a stand of oaks and pines (Table 1). Like the northern yellow bat, the eastern pipistrelle roosted in clumps of Spanish moss. However, unlike the other bats tracked on Sapelo, all roosts of the eastern pipistrelle were located in the understory. Two roosts were in eastern red-cedars (*Juniperus virginanus*), four in live oaks, two in yaupon (*Ilex vomitoria*), and one each in a sparkleberry (*Vaccinnium arboreum*), red bay (*Persea borbonia*), and slash pine. The overstory surrounding the roosts of the eastern pipistrelle were composed of eastern red-cedars, live oaks, laurel oaks, and black cherries (*Prunus serotina*). Because the eastern pipistrelle roosted in the understory, average heights of the roosts were lower than average heights of the other bats we tracked (Table 2). Roosts were most commonly located on the northeastern side of the roost trees.

Descriptions of tree roosts used by the eastern pipistrelle, like those for the tree roosts of other bat species, have been qualitative rather than quantitative. Findley (1954) reported that he found an eastern pipistrelle roosting in a tree in Mexico, but did not give a description of the roost. Jennings (1958) reported on the collection of 40 eastern pipistrelles from Spanish moss in Florida, but again, quantitative descriptions of the roosts are lacking. While there are few documented reports of the eastern pipistrelle roosting in trees, anecdotal evidence suggests many individuals of this species may inhabit trees throughout summer months (Menzel et al., 1996).

These data provide insight into the summer roosting habits of four species of vespertilionid bats. Future conservation of these species depends on an understanding of their roosting habits. Predictable temporal shifts in selection of roosts have been documented for many species (Fujita and Kunz, 1984; Humphrey, 1975; Jennings, 1958). It is reasonable to assume the selection of roosts by the northern yellow bat, Seminole bat, evening bat, and eastern pipistrelle also vary throughout the year and more studies are needed to document the characteristics of roosts used by these species at other times of the year. Although the roost characteristics of the northern yellow bat and eastern pipistrelle were described based on multiple roosts of only one individual, these data are valuable because so little is currently known about the characteristics of roost trees selected by these species. The summer roost trees of many more individuals of the four species involved in this study need to be characterized to examine variation in characteristics of roosts between individuals of the same species.

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KEMP'S RIDLEY (*LEPIDOCHELYS KEMPI*) NESTING IN FLORIDA

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ABSTRACT: *Kemp's ridley is one of the world's most endangered vertebrates. The primary nesting site of the species is Rancho Nuevo, Tamaulipas, Mexico; secondary nesting beaches are located near Rancho Nuevo. Isolated nesting has occurred at various other locations within the Gulf of Mexico, and more recently on the eastern coast of the United States. We report the first confirmed nesting of a Kemp's ridley on the eastern coast of Florida (two nests in Volusia Co.) and an additional nesting on Florida's west coast (Lee Co.). Genetic analysis showed that hatchlings from one of the Volusia Co. nests were pure* L. kempi *and not hybrids. Including the nests reported here, five* L. kempi *nests, involving three individual turtles, have been confirmed on Florida's beaches thus far. There is no evidence that these individuals were part of the Kemp's ridley headstart program, although that possibility cannot be excluded.*

THE Kemp's ridley, *Lepidochelys kempi* (Garman), has experienced a precipitous population decline over the past 50 years. In 1947 an estimated 40,000 females came ashore at the primary nesting site, Rancho Nuevo, Tamaulipas, Mexico, during a mass nesting event, known as an "arribada" (Carr, 1963; Hildebrand, 1963). When a conservation and monitoring program was initiated in 1966, only an estimated 2,000 females arrived at Rancho Nuevo (Márquez, 1994). The population continued to decline during the next decade but now appears to be increasing (Márquez, 1994; Márquez et al., 1996; TEWG, 1998). Egg harvest and occasional harvest of subadults and adults were blamed for the initial decline, and mortality after 1966 was primarily due to shrimp trawlers. The recent increase has been attributed to binational protection of nesting adults and clutches in Tamaulipas, a head-starting program, and implementation of turtle excluder devices (TEDs) in the U.S. shrimp trawl fleet (Hildebrand, 1963, 1995; Ross et al., 1989; Na-

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tional Research Council, 1990; Márquez, 1994; Pritchard, 1997a; TEWG, 1998).

The vast majority of Kemp's ridley nesting activity occurs at a single beach, Rancho Nuevo, located in the western Gulf of Mexico in the state of Tamaulipas, Mexico. Additional nesting beaches are known in this state, including Barra del Toro to the south of Rancho Nuevo, Barra de Ostionales to the north, and the beach at Tecolutla in the state of Veracruz (Ross et al., 1989; Márquez, 1994; Márquez et al., 1996).

Isolated nesting by Kemp's ridleys has been documented at other locations in the western Gulf of Mexico, mostly on Mexican beaches (Ross et al., 1989; Márquez, 1994); however, a few nests have been documented in the United States. In the U.S., nesting individuals have been observed on beaches in Texas (Shaver and Caillouet, 1998), North Carolina and South Carolina (Anonymous, 1992; Palmatier, 1993; Bowen et al., 1994), and on the west coast of Florida (Meylan et al., 1990a, b; 1995).

We report the first confirmed observation of a Kemp's ridley nesting on the east coast of Florida, document an additional nesting of the species on Florida's west coast, and review previous records of *L. kempi* nesting in Florida. We also provide data on success of nests deposited during the 1996 season. Because there is potential for hybridization between Kemp's ridley females and loggerhead (*Caretta caretta*) males (Karl et al., 1995), particularly in the nearshore waters of east Florida during the summer, we conducted genetic analyses to determine paternity of a few hatchlings; we present the results of these analyses for one east-coast nest. Production of hybrid progeny by Kemp's ridleys that nest in Florida has important implications for the potential of colony establishment. We conclude by speculating on the origin of the Florida Kemp's ridleys.

METHODS—Nesting turtles were initially encountered by members of the public and reported to turtle patrol organizations responsible for monitoring sea turtle nesting activity in 1996. Due to threat of tidal inundation and erosion, one nest was relocated within 4 hours of deposition to a safer site a few kilometers from the original nest site. A few weeks prior to hatchling emergence this nest was covered with a self-releasing wire cage to prevent predation. The other two nests were left *in situ*. The precise location of each clutch was marked, and nest sites were monitored for signs of disturbance and hatchling emergence. After hatchlings emerged, the contents of each nest were examined to determine success of the nest. Nesting females were photographed and voucher specimens (dead hatchlings) were collected from each nest and deposited at the Florida Museum of Natural History, University of Florida (specimen nos. 105524–105539 and 105566–105570, see Table 1).

Hatchlings from the Ponce Inlet nest (n = 30) were examined to determine if they exhibited any hybrid characteristics. Straight-line carapace length (SLCL, nuchal notch to tip of shell) and width (SLCW) were measured to the nearest 0.1 mm with a vernier caliper, and weight was determined to the nearest 0.1 g with a digital balance. The number of costal and inframarginal scutes was counted on the left side of each turtle, and coloration of carapace and plastron was noted.

Hatchlings from the Ponce Inlet nest (n = 4) were examined with molecular genetic markers to test for hybrid characteristics. We isolated whole genomic DNA from muscle samples of dead hatchlings. Isolations were conducted using standard phenol/chloroform method-

TABLE 1. Voucher specimens and photos in the Florida Museum of Natural History collection, University of Florida, from the three Kemp's ridley nests documented in Florida in 1996.

Nesting date	County	UF catalog #s	Description
10-May-96	Lee	105566–105569	Four dead hatchlings.
10-May-96	Lee	105570	18 color photographs of the adult female taken by residents Martin and Mille Allen.
14-May-96	Volusia	105528–105538	Five dead hatchlings and six dead fetuses from the Ponce Inlet nest.
1-Jun-96	Volusia	105524–105527	Two dead hatchlings, one pipped dead turtle, and one dead fetus from the New Smyrna Beach nest.
1-Jun-96	Volusia	105539	Three color photographs of the adult female taken by Marye Marshall.

ology (Hillis et al., 1996). Because the nesting female exhibited morphological features of *L. kempi,* we assumed that she was not a hybrid. We conducted polymerase chain reactions using primers pdCM-12R and pdCM-12L of Karl and co-workers (1992). These primers amplify an anonymous single-copy locus within the nuclear genome. Four nonhybrid specimens of the following species were amplified for comparison to the potential hybrid hatchlings: loggerhead turtle (*Caretta caretta*), green turtle (*Chelonia mydas*), hawksbill turtle (*Eretmochelys imbricata*), and Kemp's ridley (*L. kempi*). The CM-12 locus was used because digestion with the restriction enzyme *Rsa* I generates species specific banding patterns. These fragment-digestion profiles distinguish loggerhead from Kemp's ridley and green turtle or hawksbill from Kemp's ridley (for more details see Karl et al., 1995). The amplified locus was digested with *Rsa* I according to the manufacturer's instructions (Life Technologies). Resulting fragment digestion profiles were visualized in a 2% agarose gel stained with ethidium bromide.

RESULTS—*Nesting activity*—On 14 May 1996, at ca. 1400 h EST, a Kemp's ridley came ashore and nested on the beach at the town of Ponce Inlet, Volusia Co., FL. The turtle nested at the northern edge of a maintained vehicular access ramp (Old Timers approach). After the female completed the nesting process, she was measured with forester's tree calipers, examined for tags and tag scars, and photographed. No evidence of metal tags, tag scars, or living tags (see Fontaine et al., 1993) was observed, and we did not tag her. She had a SLCL of 63.8 cm and a SLCW of 61.5 cm. Initially the clutch was left in place; however, when the site was checked four hours later, it was in imminent danger of tidal inundation, and erosion of the site was deemed likely. For these reasons the clutch of 108 eggs was relocated to a safer site a few kilometers south of the initial location.

On 1 June 1996, at ca. 0800 h EST, the same female nested at New Smyrna Beach, Volusia Co., behind the residence at 1007 Hill Street. This site is approximately 7 km south of the first nest location. Photographs of this animal were compared to photos taken during the 14 May nesting. Although no significant carapace damage was seen, a few cosmetic flaws (neck-skin pigmentation and small pits in the carapace, Fig. 1a) allowed

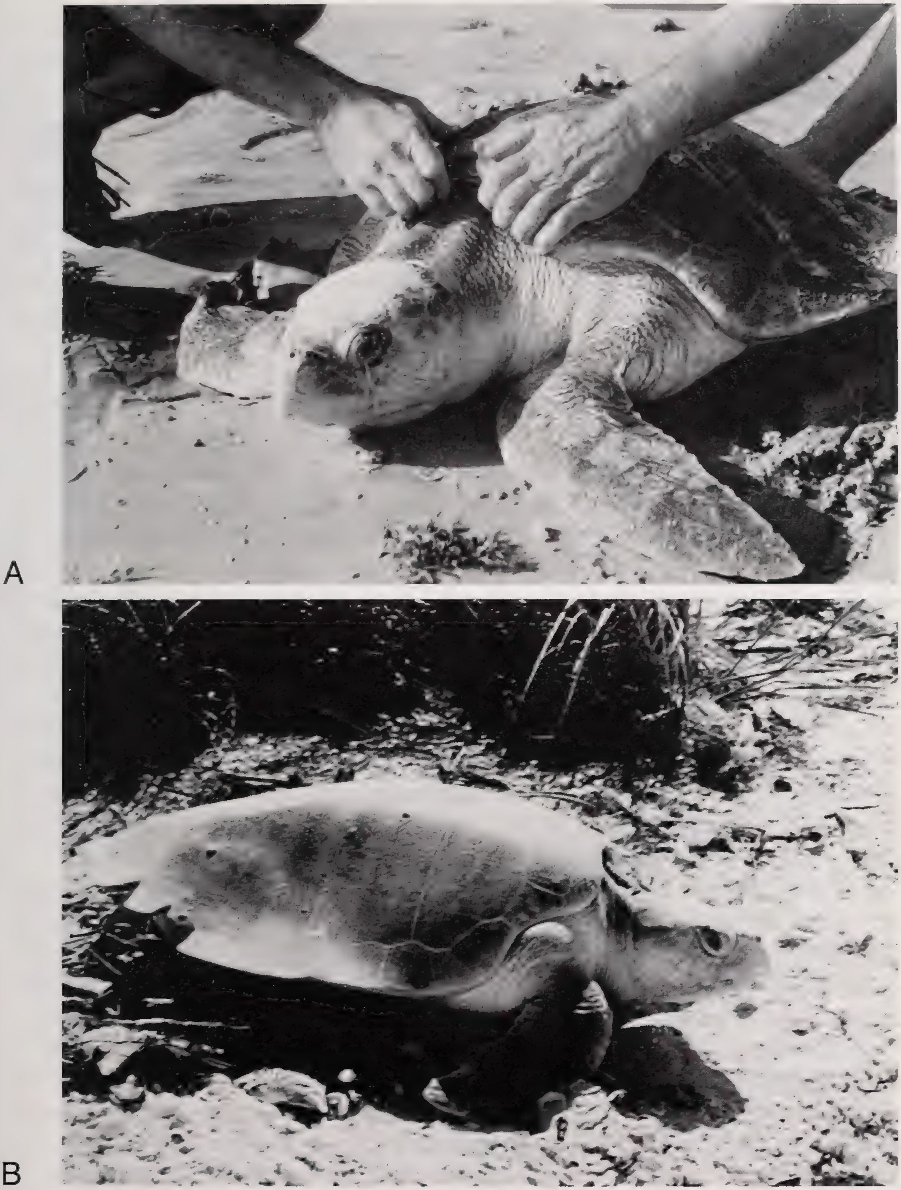

FIG. 1. Kemp's ridleys that nested in Florida in 1996. a. Post-nesting female, Volusia Co., 1 June 1996. b. Post-nesting female, Lee, Co., 10 May 1996.

positive identification as the same turtle in both instances. Both emergences occurred during the day and during periods of strong onshore winds and rough surf. Daytime nesting during high winds and rough surf is typical for the species (Márquez, 1994).

A Kemp's ridley nest also was observed on the west coast of Florida in 1996. This nesting took place during midmorning (specific time not recorded) on Sanibel Island, Lee Co. The clutch was deposited behind the residence at 3735 West Gulf Drive on 10 May 1996. Biologists with the Florida Department of Environmental Protection compared photographs of the Sanibel turtle with photos of the two other Kemp's ridleys that nested in the state during previous years (see below). Because of a distinctive area of damage to the carapace visible in photos of the Sanibel turtle (Fig. 1b), state biologists concluded that this turtle was the same individual that nested in 1994 at Clearwater Beach (Foley, 1997a) approximately 200 km north of Sanibel Island.

Success of nests in 1996—Hatchlings emerged from the Ponce Inlet nest on the evening of 17 July between 2100 and 2200 h EST after a 64-day incubation period. Thirty of these were closely examined (see below). The success of the nest was evaluated three days later. Of the 108 relocated eggs, 85 hatched (hatching success = 78.7%) and 80 hatchlings emerged from the nest (hatchling emergence success = 74.1%); the other five were found dead in the nest chamber. Thirteen eggs did not hatch; ten eggs contained turtles that pipped the shell but were unable to extricate themselves from the egg.

The New Smyrna Beach nest never showed any sign of hatchling emergence. A single Kemp's ridley hatchling was found washed ashore on 9 August near the nest. Another hatchling was found dead on the sand surface at the nest on 10 August, apparently depredated by ghost crabs (*Ocypode quadrata*). On 14 August 1996, 75 days after oviposition, the nest was evaluated. Of an estimated clutch size of 94 eggs, eight hatched (hatching success = 8.5%), 85 did not hatch, and one turtle pipped the shell but was unable to extricate itself from the egg. One of the unhatched eggs contained an albino fetus with deformities to the head and shell. One live hatchling was found with severe deformities to the head (microcephaly and lacked functional eyes) but was released in the surf. Three hatchlings were found dead (hatchling emergence success = 4.3%).

Hatchlings emerged from the Sanibel Island nest on 30 June at ca. 0645 h EST after a 51-day incubation period. The next day three dead hatchlings were discovered on the beach near the nest site. Two additional dead hatchlings were found the following morning, also near the nest. On 3 July 1998 the nest was evaluated to determine success of the clutch. Of an estimated 136 eggs deposited, 126 hatched (hatching success = 92.6%), nine did not hatch, and one turtle pipped the shell but was unable to extricate itself from the egg. The turtle that pipped the shell was still alive and it was released with a live hatchling that was also found in the nest (hatchling emergence success = 91.9%).

Photographs of the adults and voucher specimens (dead hatchlings and fetuses) were placed in the Florida Museum of Natural History. Information regarding the specimens and photos can be found in Table 1.

Hatchling phenotypes and genetic analysis—The east coast of Florida annually hosts one of the world's largest nesting aggregations of the loggerhead turtle (Meylan et al., 1995). Because of the presumed large number of male loggerheads in the nearshore waters, it is possible that the Kemp's ridley that nested on the east coast could have been inseminated by a loggerhead. Hybridization between these two species is known to occur. Karl and co-workers (1995) reported a juvenile sea turtle from Chesapeake Bay, which "appeared to be the F_1 product of a cross involving a Kemp's ridley female and a loggerhead male." Therefore, we had reason to suspect that hatchlings from Florida nests could include *Lepidochelys* X *Caretta* hybrids.

Suspected marine turtle hybrids are often initially identified by phenotype, usually exhibiting "intermediate features in otherwise diagnostic morphological characters" (Karl et al., 1995). With this in mind, we examined thirty of the hatchlings from the Ponce Inlet nest. All hatchlings examined were a uniform charcoal gray color, characteristic of Kemp's ridley hatchlings (Pritchard, 1979), rather than the brownish-red color characteristic of *Caretta* hatchlings from the east coast of Florida (S. A. Johnson, personal observation). All but one of the hatchlings had four inframarginal scutes (one had three) rather than the three inframarginals found in the loggerhead (Pritchard, 1979). Thus, all examined hatchlings appeared to be pure *L. kempi.*

Hatchlings ranged in SLCL from 39.7 to 44.5 mm (mean = 43.1 mm) and from 34.6 to 37.4 mm in SLCW (mean = 36.2 mm). The mean mass was 16.4 g with a range from 14.0 to 17.7 g. These measurements are similar to those reported for Kemp's ridley hatchlings (National Research Council, 1990; Ernst et al., 1994).

The molecular evidence further supported our supposition that the hatchlings were not hybrids. Fragment digestion profiles (Fig. 2) were generated for four of the offspring from the Ponce Inlet nest. The profiles indicated that the father of these hatchlings was not a loggerhead, green, or hawksbill turtle. The offspring profiles exactly matched that of known Kemp's ridleys. Therefore, we conclude that the father of the four offspring was a Kemp's ridley. Based on the phenotype of the hatchlings examined in the Ponce Inlet nest, as well as the few from the New Smyrna Beach nest, we assume that all hatchlings observed were pure *L. kempi.*

DISCUSSION AND CONCLUSIONS—The first documented nesting activity of *L. kempi* in Florida occurred on 30 May 1989 on Florida's west coast at Madeira Beach, Pinellas Co. (Meylan et al., 1990b). Another Kemp's ridley nested in Pinellas Co. at Clearwater Beach on 8 June 1994 (Harman, 1998). There is no published record of the 1994 event in the scientific literature, but it is referred to in the Spring/Summer edition of the *Velador,* the newsletter of the Caribbean Conservation Corporation, Gainesville, FL. Therefore, the Sanibel Island nest we report here is the third confirmed nest for the species on the west coast of Florida.

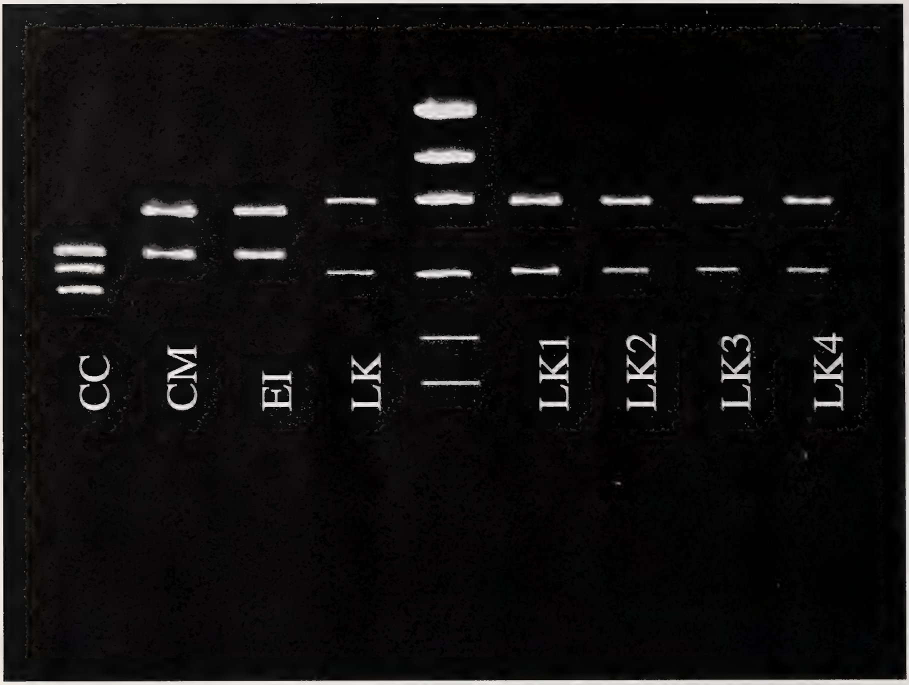

FIG. 2. Nuclear DNA restriction fragment profiles (CM-12 locus cut with *Rsa* I) for known specimens of *Caretta caretta* (CC), *Chelonia mydas* (CM), *Eretmochelys imbricata* (EI), *Lepidochelys kempi* (LK), and four hatchlings from the Ponce Inlet nest. A molecular weight standard is in the middle lane. Profiles for the four hatchlings (LK1—LK4) match the profile for the known Kemp's ridley (LK).

The two nests in Volusia Co. are the first confirmed nesting records for *L. kempi* on Florida's east coast, although one individual had earlier attempted to nest on the east coast in south Florida. On May 22, 23, 30, and 31, 1989, what was thought to be the same animal came ashore in Palm Beach Co. but did not lay eggs (Meylan et al., 1990b).

As of the end of the 1998 sea turtle nesting season, five *L. kempi* nests have been confirmed on Florida's beaches (Table 2). Three nests were observed along the west coast and two on the east coast (Fig. 3). Comparison of photographs taken during each nesting event suggest that no more than three individuals were responsible for the five nests. All nesting activity occurred during daylight, which is typical for the species, and on beaches with high levels of human activity. No evidence of tags or tag scars was observed on any of the nesting females.

Where are these females coming from? Data from molecular studies of marine turtle DNA are consistent with the idea that most female sea turtles return to their natal beach to nest (Bowen and Avise, 1996). However, this is probably not the case with the Kemp's ridleys that nested in Florida.

TABLE 2. Summary of confirmed Kemp's ridley nests in Florida through 1998 (also see Fig. 3).

Date of nesting	County	Scientific literature references to the nesting event	Comments
30-May-89	Pinellas	Ross et al., 1989; Meylan et al., 1990a, b, 1995; Bowen et al., 1994; Marquez, 1994	First confirmed nest of the species in Florida.
8-Jun-94	Pinellas	This paper	Nest referred to in the 1994 Spring/Summer issue of *Velador.*
10-May-96	Lee	This paper	Nest by same turtle that nested in Pinellas Co. in 1994.
14-May-96	Volusia	This paper	First confirmed nest of the species on Florida's east coast. Referred to in two popular articles by Pritchard (1996, 1997b).
1-Jun-96	Volusia	This paper	Nest by same turtle that nested in Volusia Co. on 14-May-96. Referred to in two popular articles by Pritchard (1996, 1997b).

Considering the conspicuous daytime nesting behavior of the species, we feel it unlikely that Kemp's ridley nesting events have gone unnoticed in Florida in the past and that these females are the progeny from such nests. The late Archie Carr spent nearly two decades searching for nesting grounds of the Kemp's ridley, and he found no evidence that individuals of this species nested in Florida (Carr, 1984). Nevertheless, we cannot rule out the

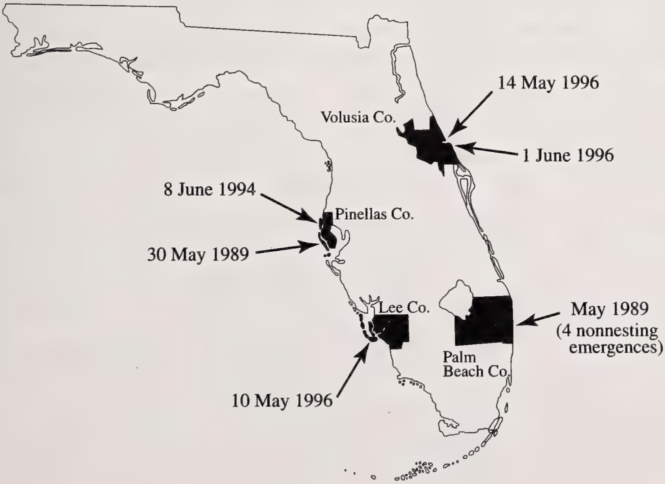

FIG. 3. Locations of all known Kemp's ridley nests and nesting attempts in Florida through 1998.

possibility that some scattered nesting historically occurred in the state. Females may have gone unnoticed or may have been misidentified as loggerheads. However, the recent appearances by Kemp's ridleys on Florida's beaches probably represent a novel event.

Another possible explanation is that these females are individuals from the Kemp's ridley headstart program (see Bowen et al., 1994). Bowen and co-workers (1994) have argued that timing of the nesting events in Florida and elsewhere along the Atlantic coast corresponds to the maturation time expected for head-started Kemp's ridleys. Indeed, a few females confirmed as head-started individuals recently nested in Texas (Shaver and Caillouet, 1998). Nevertheless, none of the Florida turtles showed any evidence of tags or scars to indicate they were products of the headstart program. On the other hand, the Kemp's ridley that nested in North Carolina in 1992 "bore a scar on the right foreleg where a tag may once have been attached" (Palmatier, 1993). Although the Florida Kemp's ridleys, as well as the females that nested in the Carolinas, could be head-started individuals, we suggest that these individuals could be colonists from the wild population (but see Bowen et al., 1994).

When they are considered over geologic time, sea turtle nesting rookeries are ephemeral (Bowen et al., 1992; Bowen and Avise, 1996). Therefore, occasional "breakdown" of natal homing behavior must occur for new colonies to be established. The Kemp's ridleys that nested in Florida may be the first "natural" (rather than head-started turtles) colonists of a future nesting rookery. There is no doubt that the number of *L. kempi* nesting at Rancho Nuevo is increasing (TEWG, 1998). Colony expansion into areas well outside the species' accepted range might be a concomitant characteristic associated with population recovery. Evidence for such a phenomenon might be the increase in nesting in southern Texas. Although head-started turtles are contributing to the increase, most individuals (10 of 16) examined for tags showed no indication of being part of the headstart program (Shaver and Caillouet, 1998). Further evidence suggesting concomitant range expansion with sea turtle population recovery can be found in the population of green turtles (*Chelonia mydas*) that nests in Florida. Although the historical size of the Florida assemblage is unclear (Carr and Ingle, 1959; Dodd, 1981; it is presumed to have been much larger historically), there has been an overall trend of increase in numbers of nests during the past two decades (Meylan et al., 1995; Foley, 1997b). During this period green turtles have been documented nesting in areas where they were not previously known to nest (Litwin, 1981; Foley, 1997b). Unfortunately, the mere absence of tags and tag scars on the Florida ridleys is not a robust test of the turtles' origins. Thus, there is no way to determine if the Florida ridleys are head-started individuals or natural colonists.

Although the nesting events in Florida and the Carolinas are unprecedented (at least in the scientific community), the possibility exists that a new Kemp's ridley colony may be in the early stages of establishment. Colony establishment is not likely to occur in the near future because the chance of a single female hatchling surviving to maturity is very low. However, additional colonists (wild or head-started individuals) could hasten the growth of such a colony. Despite the uncertain source of females, if Kemp's ridleys begin to regularly nest on Florida's beaches, natural resource managers may have to consider additional conservation measures to ensure that nesting females, nests, and hatchlings are protected from potentially detrimental beach activities.

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A REVIEW OF AIRBORNE, SOIL, AND SUBAERIAL ALGAE IN FLORIDA

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Abstract: *Algae of the three habitats are mostly unicellular chlorophytes and cyanophytes, but chrysophycean, diatom, and euglenoid taxa are often well represented. Earlier studies were concerned with identification of the organisms in relation to specific habitats, in contrast to more recent research where confident identifications and quantitative data have been obtained from laboratory and field research. The organisms cause human and animal disease, fertilize soil, and deteriorate natural and man-made structures.*

Viable algae isolated from the atmosphere, subaerial[1] and soil habitats have been documented from Hawaii (Carson, 1975); India (Gunale and Balakrishnan, 1983); Mexico (Roy-Ocotla and Carrera, 1993); Michigan, North Carolina, Texas (Schlichting, 1969, 1981); Singapore (Wee, 1982; Wee and Lee, 1980); Spain (Ortega-Calvo et al., 1993); and worldwide locations (Archibald 1990). Studies of these algae have been concerned with distribution, systematics and ecology (Metting, 1981; Nienow, 1996), dispersal of propagules (Marshall and Chalmers, 1997), control of the organisms (Grant, 1982), productivity and density in agricultural systems (Shimmel and Darley, 1985), weathering of rocks, monuments, and buildings (Danin, 1993; Hirsch et al., 1995; Krumbein, 1968; Saiz-Jimenez et al., 1990; Sand and Bock, 1991), discoloration of the surfaces of buildings (Davis and Karpook, 1996), and roofs (Amburgey, 1974; Brook, 1968), increased heat loading of human dwellings (Garty, 1990), survival after forest fire (Myers, 1996; Johansen et al., 1993), and health-related problems (Tiberg, 1987). Most taxa of the three habitats are unicellular green algae and blue-green algae, but filamentous green algae (e.g., Knapp, 1933), and algae of other groups are often represented. The organisms are known to survive under extreme environmental conditions for long periods of time (e.g., Davis, 1972; Hoffmann, 1989).

The original habitats of airborne and subaerial algae are from soil and water sources (Brown et al., 1964), and the organisms are dispersed by wind, water, animals, and humans (Brown et al., 1964; Roy-Ocotla and Carrera, 1993; Schlichting, 1964, 1979). Because these algae retain viability best in humid conditions (Edmonds, 1979; Ehresmann and Hatch, 1975), Florida is favorable to the proliferation, survival, and dispersal of the algae. Florida's large tourist industry, increased incidence of allergenic cases (Jelks, 1989), and growing human and animal populations contribute to the importance of the microorganisms to this state.

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[1] Algae on or within exposed surfaces above the soil.

In Florida, bacteria and fungi of the soil and atmosphere (e.g., Albrecht, 1958; Kuehn et al., 1995) have received considerable attention, but the algae of aerial, subaerial, and soil habitats have been largely neglected. Studies (from the north west, north central, central, and southern areas of the state) have been primarily concerned with identification and quantification of taxa, ecological aspects, health-related problems for humans and animals, deposition of calcareous matter at the surface of soils, and the deterioration of natural and man-made structures.

Older studies on Florida's airborne, subaerial, and soil algae relied on references published prior to 1960 for identifications of coccoid chlorophytes (e.g., Smith, 1950), and schemes no longer accepted for identifications of cyanophytes (e.g., Drouet and Daily, 1956; Drouet, 1968, 1981) and thus have limited value and are open to question (Friedmann, 1982). This paper reviews the taxonomy, ecology, and medical aspects of airborne, soil, and subaerial algae of Florida. Epizoic algae, epiphytic algae, algae involved in erosion of rocks in salt marshes, and those associated in lichens are not considered. Excluded algae can be accessed in the papers of Donn and Boardman (1988), Chatton (1952), Davis and co-workers (1989), Ginsburg (1953), Haenninen and co-workers (1993), Lukas (1974), Lukas and Golubic (1981, 1983), Marlatt and Alfieri (1981), Polderman and Polderman-Hall (1980), Sournia and co-workers (1975), and Tschermak-Woess (1988).

Soil algae—Brannon (1952) listed 24 species of blue-green algae mainly from central Florida. Smith and Ellis (1943), Smith (1944), and Smith and Gall (1944) reported the occurrence of green algae (mostly species of *Chlorococcum* and *Chlorella*) and blue-green algae in several sandy soil associations of peninsular north central Florida related to hydrogen ion concentration (pH 4.3–7.2). Arvik (1971) in north west Florida and Norton and Davis (1975, 1991) in north central Florida used culture techniques to find taxa not reported in earlier studies. However, blue-green algae were identified with schemes that are no longer accepted. Nevertheless, they reported many species of green algae, diatoms, and cyanophytes from the surface to 15 cm depths in soils where the pH ranged from 3.7 to 6.8.

Because nearly all the above studies were based on enrichment cultures, the algae may have originated from dormant structures and not played a role in the soil ecosystem. However, other studies have provided quantitative ecological data from laboratory and field using techniques similar to those suggested by Archibald (1990) and identification with schemes of Geitler (1932), Ettl and Gärtner (1995), Komarek (1986), and Bold and students (see Archibald, 1990).

Ruble and Davis (1988) identified and quantified 19 green algae, 33 blue-green algae, and 2 diatoms from marl soils of fallow potato fields (pH

7.3–8.3) of south Florida. The mean soil population was consistently above 10^5 cells per g of soil. In soils of north central Florida treated with lime and fertilizers (pH 4.2–6.0), Sukala and Davis (1994) found 20 species of cyanophytes at 3890 cells g^{-1} soil and 25 species of chlorophytes at 8511 cells g^{-1} soil. In adjacent nontreated plots (pH 4.0–5.6) the authors reported 9 species of cyanophytes at 708 cells g^{-1} of soil, and 22 species of chlorophytes at 2239 cells g^{-1} soil. Several of the filamentous blue-green algae isolated into culture fixed nitrogen. Myers (1996) demonstrated that most algae (largely coccoid chlorophytes) occurred in the upper 10 mm of the soil (158 x 10^4 cells g^{-1} soil at the surface) in acid sands (pH 4.3–4.8) of pine flatwoods of peninsular north central Florida. The near absence of cyanophytes, too sparse to be quantified, was attributed to the low hydrogen ion concentration of the soil. Algal abundance was correlated with soil moisture, not soil nutrients, in the soils (Myers, 1996). The rapid recovery of the soil algae after fire or soil sterilization was attributed to recolonization by airborne propagules and to the ability of some taxa to withstand heat.

The colorless alga *Prototheca* has been isolated from water, feces, and soil in many locations (Pore et al., 1983; Sudman, 1974). In Florida the algae have been implicated in systemic protothecosis and skin diseases in humans (Chan et al., 1990; Tindall and Fetter, 1971; Vernon and Goldman, 1983), and with nodular skin lesions (Merideth et al., 1984) and systemic prothecosis in animals (Dillberger et al., 1988). In humans, infection is usually severe and may be fatal (Heitzman et al., 1984).

Subaereal algae—Dachnowski-Stokes and Allison (1928) identified species of *Calothrix, Dichothrix, Lyngbya,* and *Scytonema* on marl that contribute to the deposition of calcareous matter at the surface of soils of the Florida Everglades. In their checklist of the algae of northern Florida, Madsen and Nielsen (1950) recorded the occurrence of unicellular and filamentous cyanophytes, chlorophytes, and *Vaucheria* sp. from various subaerial habitats. In the Florida panhandle, Phillips (1956) described 44 species of cyanophytes on exposed limestone cliffs and a heavily wooded limestone-walled canyon during winter and summer seasons. The dark colors imparted by the filaments and the substrata below mats of *Scytonema myochrous* (Dillw.) Ag. were spongy and porous, suggesting secretion of organic acids. In the dimly lit Marianna Cave of north west Florida, Friedmann (1979) reported the occurrence of *Geitleria calcarea,* and he also described *G. floridana* on the limestone walls of that cavern. The sheaths of both cyanophytes were heavily encrusted with carbonates.

Davis and Karpook (1996) reported the occurrence and associated problems of several species of green and blue-green algae on the buildings, walkways, and monuments on the University of Florida campus. Buildings, monuments, and concrete walkways were stained orange to rust red by tightly adherent *Trentepohlia* sp., roofs and painted surfaces were colored green to black by cyanophytes and unicellular chlorophytes, and decorative facades were blackened by filamentous cyanophytes (*Phormidium* sp. and *Scytonema* sp.), particularly in areas receiving runoff water from roofs.

Airborne algae—Airborne algae have been documented from north central Florida on the University of Florida campus (Parrando and Davis, 1972) and along an east-west transect extending from the Atlantic to the Gulf coasts of north central peninsular Florida (North and Davis, 1988). The 43 species (Parrando and Davis, 1972) and the 111 species (North and Davis, 1988) were mainly unicellular chlorophytes and unicellular and filamentous cyanophytes. Using a mechanical sampler, Parrando and Davis (1972) obtained an average of 8.7 algal cells per cubic meter of air during a 6-month period, with the largest number of algae found in spring and summer months near agricultural fields with cultivated soils or with broken surfaces prepared for planting. The dominant airborne taxa of these two reports are similar to the soil taxa of north central Florida (Norton and Davis, 1975).

Some human diseases have been associated with airborne dinoflagellates from locations on the west coast of Florida (Schwimmer and Schwimmer, 1964). Asai and co-workers (1982) and Jelks (1989) of the Tampa area commented that *Ptychodiscus brevis* or their products become airborne by the thrashing action of the surf and wind and induce cough, rhinorrhea, watery eyes, and sneezing in normal humans and wheezing in asthmatic patients. Shimoda and co-workers (1988) used human bronchial smooth muscle to conclude that airborne toxin from *Ptychodiscus brevis* triggers asthma through stimulation of cholinergic nerve fiber sodium channels. Jelks (1989) and Tiberg (1987) of Sweden mention that some children reactive to algae have hobby aquariums in their homes. Evidence involving commonly occurring airborne algae in Europe and the United States (Tiberg et al., 1995) as allergenic agents for children (McElhenney et al., 1962; McGovern et al., 1966; Tiberg et al., 1995) suggests that these organisms are probably causing widespread medical problems for humans in Florida.

Presence of marine algae in the atmosphere is the subject of few reports. Stevenson and Collier (1962) collected *Chaetoceras,* diatoms, and flagellates from the marine air of the Galveston Bay area, and Lee and Eggleston (1989) cultured several airborne genera in marine media from the New England coast. In Florida, Maynard (1968) isolated marine *Pyramimonas* and *Coccolithus* from the air 40 miles inland from the coastline.

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RELATION OF TEMPERATURE AND RAINFALL TO MOVEMENTS AND REPRODUCTION OF THE EASTERN NARROWMOUTH TOAD (*GASTROPHRYNE CAROLINENSIS*) IN SOUTH-CENTRAL FLORIDA

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ABSTRACT: *Movements and reproduction were studied in a population of eastern narrowmouth toads,* Gastrophryne carolinensis, *in south-central Florida. Nearly all adult movements occurred in association with the presence of gravid females (May–September) which closely overlapped the nocturnal calling season (May–October). Seasonal movements related to reproduction occurred when monthly volume of rainfall was at least 10.8 cm and mean thermal minima and maxima were 16.2 °C and 34.4 °C, respectively, in 1994. Nightly values of rainfall and temperature associated with movements corroborated the seasonal restrictions within which reproductive activity in* G. carolinensis *occurred. Breeding season records from other locations exhibit an abrupt latitudinal shift to a highly restricted breeding season in the northernmost populations, which correlated with thermal thresholds observed in this study. Therefore, for* G. carolinensis, *climatic constraints dictate its breeding season and ultimately determine the northern limit of its geographic range.*

THE eastern narrowmouth toad (*Gastrophryne carolinensis*) is a fossorial species associated with a variety of habitats in eastern United States, including Florida (Wright, 1931; Carr, 1940; Duellman and Schwartz, 1958; Conant and Collins, 1991). Rangewide, the calling season for this species extends from April through October (Carr, 1940; Einem and Ober, 1956; Anderson, 1954; Johnson, 1987). Movements, calling, and oviposition are strongly associated with summer rains (Deckert, 1914; Wright, 1931; Anderson, 1954; Dodd, 1995). However, relating temperature and rainfall to the nightly and seasonal activities of *G. carolinensis* and using those threshold values as predictors of the reproductive season does not exist for this species. Recording pertinent environmental parameters associated with the movements of exclusively adult *G. carolinensis* enabled us to identify the criteria for movements related to reproduction and then compare climate-related predictions of breeding season with reports from the literature.

MATERIALS AND METHODS—We collected specimens at a rural homesite on the Archbold Biological Station about 13 km south of Lake Placid, Highlands Co., Florida. The 4 ha rectangular property is bordered on two contiguous sides by oak-hickory scrub. A third side is bordered by improved pasture, and the fourth by a rural two-lane paved road and citrus grove.

Less than 1 ha of mowed lawn surrounds the home and an adjacent swimming pool, both built in the 1960s. The 9.1 X 4.6 m swimming pool is bordered by a 2.7 m concrete apron. The remaining land is comprised of grass unmowed for four years (mostly the exotic Natal grass, *Rhynchelytrum repens*), scattered slash pines (*Pinus elliottii*), weeds, palmettos, and scattered shrubs, mostly oaks (*Quercus* spp.).

During January–December 1994, the swimming pool was checked each morning for *G. carolinensis.* Many individuals were freshly dead when collected. All specimens were fixed in 10% formalin and stored in 70% ethanol in the vertebrate collection at Archbold. Before fixing, snout-vent length (SVL) was measured to the nearest 0.1 mm with a vernier caliper. Sexual maturity was determined by the condition of the gonads. Enlarged testes and epididymides were used as criteria of maturity in males. Presence of yolking follicles was the criterion of sexual maturity in females. Potential clutch size for eight females was estimated by extrapolating from the mass of 100 mature ova. The entire clutch and 100 ova were weighed to 0.0001 g on an electronic balance. Mean oval diameter was estimated from 40 mature ova from five females. Using fresh material, the relative clutch mass of one female (28 mm SVL) was calculated using the following equation: clutch mass/ clutch mass + body mass. Nightly values of rainfall (cm), relative humidity (RH), and air temperature (°C) were recorded at the Archbold weather station located 1.2 km north of the collection site. During this study, additional specimens were opportunistically collected from the Lake Placid area to provide additional information on activity and reproductive characteristics.

Calling was recorded at the MacArthur Agro-Ecology Research Center (MAERC), 12 km east of Archbold Biological Station, during nightly visits from October 1993 to September 1994. Nightly rainfall (cm), relative humidity (RH), and air temperature (°C) associated with calling were recorded at the MAERC weather station. Mean values are followed by ± 2 standard deviations. All statistics were calculated using SYSTAT. Significance values of T-tests were two-tailed, and statistical significance was determined at an alpha level of 0.05.

RESULTS—*Seasonal activity*—All 57 individuals we collected were adults: 24 males (25.7 ± 2.7 mm SVL; range = 19.8–29.3) and 33 females (26.4 ± 3.2 mm SVL; range = 20.0–33.0), and all were taken during March–November. However, 95% of the individuals and all of the gravid females were collected during May–September (Table 1). At this time movements were strongly bimodal with males and primarily gravid females captured in May, and primarily spent females captured in September (Table 1). The sex ratio of adults was equal (X^2, $P > 0.05$), and mean adult body size did not significantly differ between the sexes (T-test, $P > 0.05$). Gravid females, with large ova (0.9 ± 0.1 mm; range = 0.6–1.1; N = 40), produced large clutches (928.8 ± 238.1; range = 536.3–1,223.4; N = 8) of potentially high relative clutch mass (0.613). Seasonal activity accompanying reproduction did not commence until monthly rainfall was at least 10.8 cm and mean monthly thermal minima and maxima were 16.2 °C and 34.4 °C, respectively (Table 2). Thus, it was insufficient monthly rainfall that obstructed breeding migrations in April, July, and October, and low temperatures, despite acceptable rainfall, that curtailed movements in November. During December–March, neither the necessary monthly rainfall nor the minimum and maximum air temperatures were met. Based on these monthly threshold values for rainfall and temperature (± 1.3 cm and 0.3 °C, respectively), the historic seasonal norm for reproduction-related movements for *G. carolinensis* in Lake Placid has been May–September (Table 2), with breeding

TABLE 1. Numbers of male and female *Gastrophryne carolinensis* collected in different months at Archbold Biological Station (ABS) and the reproductive condition of females collected from ABS and the vicinity of Lake Placid in 1994.

	Archbold			Archbold + Lake Placid		
Month	Male	Female	Total	Non gravid	Gravid	Total
Jan	0	0	0	0	0	0
Feb	0	0	0	0	0	0
Mar	1	0	1	0	0	0
Apr	0	0	0	0	0	0
May	12	12	24	3	9	12
Jun	3	4	7	4	15	19
Jul	0	0	0	0	2	2
Aug	4	1	5	2	0	2
Sep	3	14	17	15	3	18
Oct	1	1	2	1	0	1
Nov	0	1	1	1	0	1
Dec	0	0	0	0	0	0
Total	24	33	57	26	29	55

more likely to extend into October, when rainfall and temperature more closely approach acceptable conditions, than into April. Supporting this contention, a gravid female was collected and calling was heard in October 1993.

Nightly activity—Nightly activity was associated with wet conditions. Rain (2.7 ± 2.0 cm; 0.0–6.8; N = 58) fell on 82% (18/22) of the capture

TABLE 2. Values for monthly rainfall (cm) and mean minimum and maximum air temperature (°C) at ABS for 1994 and the 52 year average. Favorable days refers to days in 1994 in which minimum temperatures were ≥18°C and maximum temperatures were ≥28°C. Values in boldface type under the average data columns are those which fell within 0.28°C and 1.27 cm of the minimum level for reproductive-related captures of *G. carolinensis* in 1994.

	Rainfall		Mean minimum temp.		Mean maximum temp.		
Month	1994	52-yr average	1994	52-yr average	1994	52-yr average	No. favorable days
Jan	9.7	4.8	10.1	8.5	25.4	25.8	2
Feb	4.7	6.2	12.9	9.4	28.3	25.8	4
Mar	8.9	7.6	11.4	11.7	30.2	29.5	8
Apr	5.1	6.1	**16.1**	13.8	33.2	32.6	18
May	**10.8**	**10.9**	**16.2**	**16.4**	**35.3**	**35.1**	18
Jun	**28.8**	**21.1**	**20.2**	**19.5**	**35.9**	**35.8**	30
Jul	9.2	**22.1**	**19.4**	**20.7**	**36.8**	**37.0**	31
Aug	**22.9**	**19.2**	**19.5**	**21.1**	**36.4**	**36.9**	31
Sep	**21.1**	**21.8**	**19.8**	**20.4**	**34.4**	**34.8**	30
Oct	6.5	**10.2**	**16.1**	**17.4**	33.2	32.6	15
Nov	**10.6**	4.2	**16.0**	12.4	30.5	29.1	11
Dec	9.7	4.1	13.1	9.4	27.0	25.7	9

nights and during the movements of 91% (52/57) of the individuals captured. Nightly movements did not occur unless minimum daily air temperatures were between 18.0 and 22.8 °C (20.2 ± 1.4 °C; N = 57) and maximum daily air temperatures were between 28.2 and 38.4 °C (34.7 ± 2.4 °C; N = 57). Although April and May had equal numbers of thermally acceptable days for activity, rainfall in April was insufficient for movements, whereas 50% of the May captures and 44% of the rainfall for May occurred on a single night when 4.7 cm of rain fell. In 1994 all nights during June–September met these thermal criteria (Table 2).

Calling season and activity—During the 12 months October 1993–September 1994, nocturnal calling was recorded at MAERC on 55 nights during May–October when monthly rainfall was at least 6.9 cm and average monthly low temperatures were at least 18.0 °C. Calling also was heard at Archbold in May when monthly minimum temperature was 16.2 °C. Number of nights each month with chorusing was closely associated with monthly volume of rainfall ($r = 0.88$, $P < 0.000$). Because of a dearth of rain (2.3 cm) in November, calling ended in October. A single diurnal chorus was heard during the last week of March 1993 in Brighton, Highlands Co., 15 km south of Archbold. Based on monthly threshold values for minimum temperature and rainfall associated with calling, the historic norm for the calling season for *G. carolinensis* in Lake Placid is during May–October (Table 2). Relative humidity (87.0 ± 2.5%; 82.1–91; N = 36) was high, and rain (1.3 ± 1.9 cm; 0.0–10.7; N = 55) fell on 73% (40/55) of nights on which calling was heard. However, a significantly lower ($T_{df\,=\,111} = 4.00$, $P < 0.0001$) volume of nightly rainfall initiated calling than movements. Choruses were recorded when air temperature was between 20.5 and 27.1 °C (24.0 ± 1.3 °C; N = 55).

DISCUSSION—At our site in south-central Florida, as inferred by individuals collected from a swimming pool, movements of adult *G. carolinensis* were almost exclusively related to reproductive activities and were constrained by rainfall and temperature. In many respects, characteristics of the population we studied were similar to those of populations elsewhere. Mean adult body size of *G. carolinensis* from our site was similar to those from north-central Florida (Dodd, 1995), Louisiana (Anderson, 1954), and Georgia (Wright, 1931), mean clutch size from our site was similar to that of a Georgia population (Wright, 1931), and the sex ratio at our site was equal as was true in Louisiana (Anderson, 1954).

Rain played an important role in the movements and reproduction of *G. carolinensis* at our site, as typifies the species throughout its geographic range. For example, at our site and in north-central Florida (Dodd, 1995), seasonal activity was triggered by rain. Indeed, without minimum rainfall (10.8 cm), no movements occurred at our site despite acceptable temperatures. This was especially evident in July 1994. In contrast, below a nightly

TABLE 3. Reproductive season of *Gastrophryne carolinensis* across its geographic range. * = Savannah River Ecology Laboratory. 1 = Carr, 1940. 2 = Einem and Ober, 1956. 3 = Meshaka, unpubl. data. 4 = This study. 5 = Duellman and Schwartz, 1958. 6 = Anderson, 1954. 7 = Dundee and Rossman, 1989. 8 = Mount, 1975. 9 = Mount, 1998. 10 = Wright, 1931. 11 = Pechmann, 1998. 12 = Altig, 1998. 13 = VanDevender, 1998. 14 = Funderburg, 1955. 15 = Braswell, 1998. 16 = Brimley, 1896. 17 = Trauth, 1998. 18 = Johnson, 1987. 19 = Johnson, 1998. 20 = Bragg, 1950. 21 = Barbour, 1971.

Location	Months	Peak	Reference
Florida	April–October	June	1, 2, 3
Florida (Lake Placid)	May–October	June–September	4
Florida (Everglades)	April–October	June	3, 5
Louisiana	April–September		6
Louisiana	March–October		7
Alabama	April–September	June–July	8, 9
Georgia (Okeefenokee)	May–August	May–July	10
Georgia (SREL)*	May–September	June	11
Mississippi	May–October		12
South Carolina (Coastal)	April–October		13
North Carolina	March–September	May–June	14
Piedmont of North Carolina	April–July	May–June	15
North Carolina (Raleigh)	May–August		16
Arkansas (N.E.)	May–July		17
Missouri (S.E.)	Late May–early August	June–July	18, 19
Oklahoma	May–July		20
Kentucky	May–June		21

threshold of 18.0 °C cited above even heavy rainfall did not coax *G. carolinensis* into activity. Franz and co-workers (1995) likewise observed a decline in movements of *G. carolinensis* as evening temperatures dropped below 18.0 °C. Rainfall also was important in the initiation of choruses, although less so than for movements. Amount of rain necessary for choruses at our site was significantly less ($T_{df = 111} = 4.00$, $P < 0.0001$) than for that (3.7 ± 3.2 cm; 0.03–11.6; N = 20) of a Georgia population (Wright, 1931).

Warm air temperatures are required for calling in *G. carolinensis* throughout its geographic range (Wright, 1931; Barbour, 1941; Anderson, 1954; this study). For example, threshold temperatures associated with calling at our site were comparable to those recorded in Georgia (22.7 °C; range = 20.2–24.1) by Wright (1931) and encompassed the records of 24 and 26 °C associated with calling in Kansas (Miller, 1991).

Calling seasons of populations across the geographic range of *G. carolinensis* have two common characteristics, with exceptions noted below. First, a June calling peak (Table 3) follows the first big rainstorms of the summer when temperatures are warm. Second, at least throughout the Southeast, which includes most of the geographic range of the species, the breeding season extends from April to October (Table 3). Unlike most populations, *G. carolinensis* in south-central Florida began calling as early as late March. However, because of the paucity of reports, we propose that breeding

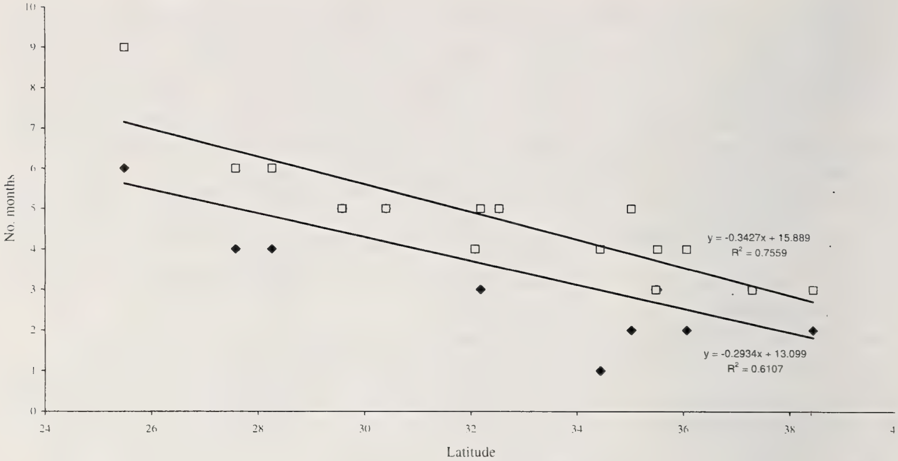

FIG. 1. Relationship of latitude to seasonal length of calling (square) and reproductive movements (diamond) in *Gastrophryne carolinensis.*

in March is rare in this species, even in south-central Florida, which has subtropical conditions marked by wet and dry seasons (Trewartha, 1954). Most March frontal systems enter Florida from the north. Occasionally these fronts include sufficient rain to stimulate reproductive activity; however, associated temperatures usually are cold enough to suppress this activity.

The April–October breeding season characteristic of the southeastern populations does not extend to the northern edge of the geographic range of *G. carolinensis* (Table 3). The latitudinal difference in the breeding season occurs abruptly near the northern-most edge of the species' range near 35 °N in Oklahoma, south-eastern Missouri, and Kentucky. At this northern latitude the length of the breeding season is short enough to be subsumed by the mid-summer peak in breeding found in the remainder of its range (Table 3). Regional differences in monthly mean values of minimum air temperatures of at least 16.2 °C, but not maximum temperatures, and regional differences in volume of rainfall of at least 10.8 cm for reproductive-related movement, and 6.9 cm for calling, correspond to the sharp restriction of the available period for reproductive activity (egglaying and calling, respectively) at the northernmost boundary of the geographic range as compared to the main body of the range. Based on long-term weather data (Wood, 1996) of average monthly minimum air temperatures (± 0.3 °C) and rainfall (± 1.3 cm), we detected a similar, and predictable geographic pattern (Figure 1; Table 4) in seasonal movements ($F = 22.0$, $P < 0.0004$) and calling season ($F = 45.4$, $P < 0.000$) to that found in the literature (Table 3).

Actual differences between our predictions and literature estimates are attributed to several causes. First, some literature values for a geographically broad state are only known for one area (Arkansas) or for the entire state

TABLE 4. Predicted seasons for reproductive-related movements and calling for *Gastrophryne carolinensis* from different localities.

City, state	Latitude	Season Movement	 Calling
Miami, FL	25.49N	May–October	March–November
Tampa, FL	27.58N	June–September	May–October
Orlando, FL	28.26N	June–September	May–October
Houston, TX	29.58N	May–September	May–September
New Orleans, LA	29.59N	May–September	May–September
Mobile, AL	30.41N	May–September	May–September
Savannah, GA	32.08N	June–September	June–September
Jackson, MI	32.19N	May–July	May–September
Charleston, SC	32.54N	May–September	May–September
Little Rock, AR	32.44	June	June–September
Memphis, TN	35.03N	May–June	May–September
Knoxville, TN	35.49N	June–August	June–August
Raleigh, NC	35.52	June–August	June–September
Nashville, TN	36.07N	June–July	June–September
Richmond, VA	37.30N	June–August	June–August
St. Louis, MO	38.45N	June–July	June–August

(Louisiana), whereas our values specify one locality. Second, a literature value may encompass a long temporal scale, such as North Carolina (Funderburg, 1955) or Mississippi, thereby capturing extremes as compared to norms of our predictions. Nonetheless, the reproductive seasons as predicted by weather and the reproductive seasons reported in the literature closely overlap cities and latitudes. Together, they share the pattern of an abrupt restriction in the breeding season, especially egglaying, at the northern-most latitudes. In a broader context, the geographic range of *G. carolinensis* (Conant and Collins, 1991) nearly overlaps the Humid Mesothermal Climate of Koppen (Humid Subtropical) of southeastern United States (Trewartha, 1954). The northern edge of its geographic range interfaces with the Humid Microthermal Climate of Koppen (Humid Continental) and closely follows the region between the 1.7 and −1.1 °C winter isotherms (Trewartha, 1954). Consequently, as the species approaches a winter climatic barrier to residency in the north, cooler temperatures despite adequate rainfall, severely restrict the breeding season.

At the southern extreme of its geographic range, the opposite is true. Ocean barriers, not climate (Tropical Rainy Climate of Koppen as Tropical Wet and Dry) define the southern end of the species' range. The season favorable for calling in Miami exceeds that of the observed calling season by two months. Human-altered hydrological patterns of southern Florida could be responsible for this difference if, for example, water table levels are too low in Miami to maintain standing water for calling in March and November. Just as plausible an explanation for the rarity of March and April calling records and the absence of November calling records is the possibility of constraints in the gonadal cycle of *G. carolinensis,* whereby the species is unable to respond reproductively to the extended amenable weather conditions historically present in extreme southern mainland Florida.

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VIRTUAL REFERENCE WETLANDS FOR ASSESSING WILDLIFE

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ABSTRACT: *The wildlife function and value of a wetland is typically assessed by comparison with an idealized or actual standard. Described here is an alternative approach that uses Virtual Reference Wetlands (VRWs) as the standard for comparison. VRWs are established by compiling a list of all wildlife species occurring in regional wetlands from available literature. VRWs are applicable to a variety of assessment situations. The VRW approach was applied to wildlife use of a created wetland to illustrate the utility of VRWs. The created wetland wildlife community was found to be relatively rich, due in part to the occurrence of upland birds. Consistent with its physical characteristics, the wildlife community more closely resembled that of freshwater marshes of the region. Habitat specialists were just as likely to occur in the created wetland as were habitat generalists. VRWs would likely be of comparable value in other assessment situations.*

TWO fundamental approaches have been used to assess the wildlife function and value of wetlands. In one approach, wildlife function and value are assessed by comparison with an ideal standard (U. S. Fish and Wildlife Service, 1976; Adamus et al., 1987). Optimal habitat conditions (e.g., tree density, water depth, etc.) are established for individual species empirically or by consensus. Conditions in the focal wetland are then compared to these optimal conditions, resulting in an assignment of relative function and value for target species. Function and value are extrapolated to other species through guilding, i.e., grouping species that use a common resource in the environment.

The other approach assesses wildlife function and value by comparison with an actual reference wetland(s) standard (Kent et al., 1992; Kentula et al., 1992; Brinson, 1996). The comparison may be based upon habitat conditions, in which case this approach resembles the first approach, or on actual observations of wildlife occurrence.

Both approaches provide for relatively rapid, repeatable assessment of wildlife function and value. Nevertheless, the assumptions intrinsic to these approaches constrain the information, and confidence, that can be derived from the assessment. The use of idealized or actual standards using habitat conditions indicates the potential use, rather than the actual use, of wetlands by wildlife. The relationship between habitat attributes and function are not always predictable, especially given the paucity of our knowledge regarding landscape-scale effects.

Use of a reference wildlife population overcomes the assumption that apparently appropriate wildlife habitat is actually used by wildlife. However, this requires selection of an appropriate reference wetland(s), a task that is far from trivial. In many instances, finding a reference wetland with closely similar internal characteristics and landscape characteristics will be difficult, if not impossible. Moreover, comparison of a pair of sites does not provide information that can be extrapolated with known certainty to other wetlands.

Described here is an alternative or supplemental approach to assessing wetland wildlife function and value that commingles previous approaches. An idealized standard, the Virtual Reference Wetland (VRW), is established by compiling a list of all wildlife species occurring in regional wetlands. The VRW can represent wildlife of all wetland types in the region, or can be partitioned by wetland type. Moreover, the VRW can represent wildlife of all seasons, or any particular season. Wildlife of the focal wetland, determined through direct observation, is then compared to the VRW.

The VRW approach has several useful characteristics. First, as with the other approaches, VRWs provide for a repeatable, and in some instances, relatively rapid, assessment of wetland wildlife function and value. Second, VRWs are easily established for various wetland classification schemes and geographic scales. Field guides, federal and state agency lists, scientific publications, and gray literature are readily available. Third, both the VRW and the focal wetland wildlife list are based upon direct observation of wildlife, thereby providing for evaluation of actual rather than potential function and value. Fourth, the VRW approach eliminates the need to identify a reference wetland that reasonably establishes an appropriate standard. Fifth, the use of an idealized standard, rather than an actual reference wetland, will reduce project costs and facilitate extrapolation of the findings to other wetlands. Sixth, the VRW is a relatively immutable standard, because the regional wildlife community is less subject to change over the short term than the wildlife community of any single wetland. And finally, the VRW provides for calculation of various metrics including relative richness, similarity, and the proportion of upland/wetland species and habitat generalists/specialists. These metrics can be compared at several temporal and spatial scales. As with other assessment techniques, a good sampling design will be necessary to account for climatic and seasonal variation.

VRWs have several limitations; the most significant of which is an inability to compare wildlife abundance. VRW assessments will be, in many instances, limited to vertebrate wildlife, as information about invertebrate wildlife is generally incomplete. The VRW requirement for direct observation will result in less rapid assessments than techniques relying solely on indicators. Also, the degree of resemblance between the focal wetland and the VRW is limited by the composite nature of the VRW. That is, it is unlikely that any but the largest wetlands will be found to support all of the species of the VRW.

The VRW approach is applicable to a variety of assessment situations. For example, a VRW can be used to establish the relative value of a population of wetlands as part of an alternative analysis. A VRW also lends itself to assessing the success of enhancement, restoration, and creation efforts. To illustrate one use of VRWs, we apply the approach to observations of wildlife use in a created wetland.

STUDY AREA—The study was conducted in Lake Buena Vista, Orange County, east central Florida, United States. Prior to construction of the created wetland, the study area was characterized by nearly level Pomello and Immokalee fine sands with a seasonal high water table ranging from 25 cm to 100 cm below the substrate surface. Vegetation consisted primarily of longleaf pine (*Pinus palustris*), sand pine (*P. clausa*), and slash pine (*P. elliottii*) forest. The study area is bordered by a narrow grass strip and divided roadway to the east; oak scrub forest to the north, northwest, and southeast; and cypress and hardwood swamp to the west and south.

Construction of the 31.6 ha (78 acre) created wetland was completed during the first week of July, 1992. Lower elevations, comprising approximately 20 percent of the wetland, were planted with pickerelweed (*Pontederia cordata*) and arrowhead (*Sagittaria lancifolia*). Water lily (*Nymphaea odorata*) and rush (*Juncus effusus*) subsequently invaded the lower elevations of the wetland and comprised a significant part of the herbaceous cover. Droughty conditions existed during the first month; thereafter water levels ranged seasonally from 1.0 to 1.3 m above the substrate surface.

The balance of the wetland was broadcast with maidencane (*Panicum hemitomon*) rhizomes, and planted with 3.8 L (1 gallon) trees including red maple (*Acer rubrum*), water ash (*Fraxinus caroliniana*), loblolly bay (*Gordonia lasianthus*), dahoon holly (*Ilex cassine*), magnolia (*Magnolia virginiana*), water tupelo (*Nyssa aquatica*), swamp bay (*Persea palustris*), and cypress (*Taxodium ascendens*). Various herbs, including sedge (*Cyperus spp.*), Bermudagrass (*Cynodon dactylon*), wildmillet (*Echinochloa walteri*), rush, and paspalum (*Paspalum urvellei*) invaded the area. Water levels ranged seasonally from 0.3 m above the surface to 0.6 m below the surface. There was no significant change in plant species composition or structure during the course of the study.

METHODS—The wetland was sampled quarterly from 27 July, 1992 through 12 August, 1994. Sampling events commenced in July and October, 1992; January, April, July, and October, 1993; and January, April, and July, 1994. Each sampling event lasted three weeks; within each week, wildlife were sampled using pedestrian transects, scan sampling, and auditory sampling.

Two separate and non-overlapping pedestrian transects were selected from construction survey drawings to provide coverage of the majority of the wetland. Each transect was permanently marked with stakes in the field. Once per period, two field biologists walked the transects approximately one half-hour after sunrise and again at noon. Recent signs of wildlife such as nests, tracks, and scat were also recorded as wildlife observations.

Scan sampling was effected at 12 stations permanently established and marked along the perimeter of the wetland. Collectively, these stations permitted observation of the entire wetland. Scan sampling was conducted three times per day (approximately one half hour after sunrise, noon, two hours before sunset) one day per week using binocular and spotting scope. Five minutes of direct observation were completed at each station. Observers attempted to avoid duplicate recording of individual wildlife.

Auditory sampling of frog and toad vocalizations was conducted at these same 12 stations once per week. Incidental observations of other wildlife were also recorded. Sampling commenced approximately one half-hour after sunset, and five minutes of direct listening time was effected at each station. The number of individuals of each species was estimated at each station. Again, observers attempted to avoid duplicate recording of individual wildlife.

The VRWs (Table 1) were generated from Brown and co-workers (1989) with amendments deriving principally from Myers and Ewel (1990). Wildlife species are identified with one or more wetland types of east central Florida: freshwater marsh, cypress swamp, hardwood swamp, hammock, flatwood, or sandhill. Species that might occasionally use wetlands, but are more commonly associated with uplands, are not included in the VRWs.

Wildlife species richness of the created wetland was compared with each VRW. Species composition was compared with the VRWs using the Jaccard Index (Ludwig and Reynolds, 1988). The index ranges from zero to one, with zero indicating no overlap in species and one indicating complete overlap in species. Upland species are operationally defined as species not occurring in any of the VRWs. Habitat generalist species are operationally defined as occurring in three or more of the six VRWs, and habitat specialist species as occurring in two or less of the VRWs.

RESULTS AND DISCUSSION—The created wetland was used by 103 species of wildlife between July, 1992 and July, 1994, including nine amphibians, six reptiles, 78 birds, and 10 mammals (Table 1). Total richness of the created wetland was greater than that of hardwood swamp, cypress swamp, sandhill, and freshwater marsh VRWs, and slightly less than the VRW richness of hammocks and flatwoods. Created wetland reptile richness was considerably less than the richness of the VRWs. Amphibian richness was roughly comparable to freshwater marsh VRW, but less than that of other VRWs. Mammal richness was slightly greater than that of the VRWs. Bird richness was considerably greater than that of the VRWs, due in part to the occurrence of upland birds ($n = 32$ birds).

Overall, the wildlife species composition of the created wetland bore a greater resemblance to the freshwater marsh VRW (0.40) than to other VRWs (0.22 to 0.27). This is consistent with the physical characteristics of the created wetland. At the class level, bird and mammal fauna of the created wetland most closely resembled the freshwater marsh VRW (0.43 and 0.64, respectively), and the amphibian fauna most closely resembled the hammock (0.33) and sandhill (0.38) VRWs. The latter is somewhat surprising given that wildlife are thought to initially disperse from nearby habitats (MacArthur and Wilson, 1967; Wilson and Willis, 1975), and the nearest wetlands are hardwood and cypress swamps. Reptiles bore little resemblance to any VRW, due largely to the small number of reptiles species observed. Eliminating upland species from the comparison increases the degree of cumulative, bird, and mammal resemblance to the VRWs by 26 to 28 percent, but does not change the pattern of resemblance.

Of the 69 wetland species observed in the created wetland, 46 were generalists and 23 were specialists. This is not significantly different ($\chi^2 = 1.85$, $0.25 > p > 0.10$, 1 df) than the ratio of generalists to specialists in the VRWs (111:36). This is counter to the theory that habitat generalists are more likely than habitat specialists to use new habitats (Case, 1975; Pisarki and Kulesza, 1982; Parsons, 1983; Orians, 1986; Enckell et al., 1987; Recher, 1989; Thornton et al., 1990). It may be that the relatively small potential

TABLE 1. Wildlife of the created wetland and Virtual Reference Wetlands of east central Florida.

Species	Created wetland	Freshwater marsh	Hardwood swamp	Sandhills	Flatwoods	Cypress swamp	Hammocks
Amphibians							
Acris gryllus dorsalis	x	x	x		x	x	x
Bufo quercicus	x			x	x	x	
Bufo terrestris	x	x	x	x	x		x
Desmognathus auriculatus			x		x	x	x
Eumeces laticeps			x		x		x
Eurycea quadridigitata		x	x		x	x	x
Gastrophryne carolinensis	x		x	x	x	x	x
Hyla cinerea	x	x		x	x	x	x
Hyla crucifer			x			x	x
Hyla femoralis	x		x	x	x		x
Hyla gratiosa		x	x	x			
Hyla squirella			x	x	x	x	x
Limnaoedus ocularis	x				x	x	x
Notophthalmus perstriatus		x		x	x	x	x
Pseudacris ornata			x		x	x	x
Rana areolata				x	x	x	
Rana catesbiana			x	x	x	x	x
Rana grylio	x		x	x	x		x
Rana heckscheri		x	x	x	x	x	x
Rana utricularia	x	x	x		x	x	x
Scaphiopus holbrookii hol.				x			
Reptiles							
Agkistrodon piscivorus	x	x	x	x		x	x
Alligator mississipiensis	x	x	x	x	x	x	x
Anolis carolinensis	x		x	x	x	x	x
Apalone ferox		x	x	x	x	x	x
Cemophora coccinea coccinea			x	x	x	x	

TABLE 1. Continued.

Species	Created wetland	Freshwater marsh	Hardwood swamp	Sandhills	Flatwoods	Cypress swamp	Hammocks
Chelydra serpentina		x	x	x	x	x	x
Chrysemys floridana	x	x	x	x	x	x	x
Coluber constrictor priapus	x	x		x	x		x
Crotalus horridus						x	x
Deirochelys reticularia		x	x	x	x	x	x
Diadophis punctatus punctatus				x	x	x	x
Drymarchon corais couperi				x	x		x
Elaphe obsoleta quadrivittata		x	x	x	x	x	x
Farancia abacura abacura		x	x	x	x	x	x
Farancia erytrogramma				x	x		x
Heterodon platyrhinos				x	x		x
Kinosternon baurii		x		x	x	x	x
Kinosternon subrubrum steindachneri		x	x	x	x	x	x
Lampropeltis getulus getulus			x		x	x	x
Lampropeltis triangulum elapsoides				x	x		x
Malaclemys terrapine		x	x	x	x	x	x
Nerodia cyclopion		x	x	x	x	x	x
Nerodia fasciata pictiventris	x	x	x	x	x	x	x
Nerodia taxispilota		x	x	x	x	x	x
Opheodrys aestivus				x	x	x	x
Pseudemys nelsoni		x	x	x	x	x	x
Regina alleni		x	x	x	x	x	x
Regina rigida			x	x	x	x	x
Seminatris pygaea pygaea		x	x	x	x	x	x
Sistrurus miliarius barbouri		x		x	x	x	
Sternotherus ordoratus		x	x	x	x	x	x
Storeria dekayi victa			x	x	x		x
Storeria occipitomaculata				x	x		x
Terrapene carolina bauri				x	x		x

TABLE 1. Continued.

Species	Created wetland	Freshwater marsh	Hardwood swamp	Sandhills	Flatwoods	Cypress swamp	Hammocks
Thamnophis sauritus sackenii			x	x	x	x	x
Thamnophis sirtalis siritalis		x		x	x	x	x
Trachemys scripta		x	x	x	x	x	x
Birds							
Agelaius phoeniceus	x	x					
Aix sponsa	x	x	x	x	x	x	x
Ammodramus savannarum	x						
Anas americana		x	x			x	
Anas carolinensis		x	x	x		x	
Anas clypeata		x	x	x		x	
Anas discors	x	x		x	x		x
Anas fulvigula	x	x		x	x		x
Anas platyrhynchos	x	x		x	x		x
Anhinga anhinga	x	x	x	x	x	x	x
Anthus spinoletta		x					
Anthya collaris		x		x	x		x
Aramus guarauna		x	x	x	x	x	x
Archilochus colubris			x		x	x	x
Ardea herodias	x	x	x	x	x	x	x
Botaurus lentiginosus	x	x					
Bubulcus ibis	x		x	x	x	x	x
Buteo brachyurus	x		x	x	x	x	x
Buteo jamaicensis	x						
Buteo lineatus	x	x	x		x	x	x
Butorides virescens	x	x	x	x	x	x	x
Capella gallinago	x	x					
Caprimulgus carolinensis	x						
Cardinalis cardinalis	x						

TABLE 1. Continued.

Species	Created wetland	Freshwater marsh	Hardwood swamp	Sandhills	Flatwoods	Cypress swamp	Hammocks
Casmerodius albus	x	x	x	x	x	x	x
Cathartes aura	x						
Ceryle alcyon	x	x		x	x		x
Chaetura pelagica	x						
Charadrius vociferus	x	x		x			
Charadrius wilsonia		x					
Chordeiles minor	x						
Circus cyaneus	x	x			x		
Cistothorus palustris	x	x					
Cistothorus platensis	x	x					
Coccyzus americanus			x		x	x	x
Colinus virginianus	x						
Columbina passeria	x						
Contopus virens			x		x	x	
Coragyps atratus	x						
Corvus brachyrhynchos	x						
Corvus ossifragus		x	x	x	x	x	x
Cyanacitta cristata	x						
Dendroica dominica			x	x	x	x	x
Dendroica palmarum	x	x					
Dendroica pinus				x	x		
Drycopus pileatus	x						
Dumatella carolinensis	x						
Egretta caerulea	x	x	x	x	x	x	x
Egretta thula	x	x	x	x	x	x	x
Egretta tricolor	x	x					
Elanoides forficatus	x		x		x	x	x
Empidomax virescens			x		x	x	x
Eudocimus albus	x	x	x	x	x	x	x

TABLE 1. Continued.

Species	Created wetland	Freshwater marsh	Hardwood swamp	Sandhills	Flatwoods	Cypress swamp	Hammocks
Euphagus carolinus			x			x	
Falco peregrinus		x			x		
Falco sparverius	x						
Fulica americana	x	x					
Gallinula chloropus	x	x					
Geothlypis trichas	x	x	x	x	x	x	x
Grus canadensis	x	x			x		
Haliaeetus leucocephalus	x	x	x	x	x	x	
Himantopus mexicanus		x					
Hyloccichla mustelina			x		x	x	x
Ixobrychus exilus	x	x					
Lanius ludovicianus	x						
Limnothlypis swainsonii			x		x	x	x
Lophodytes cucullatus		x		x	x		x
Meleagris gallopavo	x			x	x		x
Melanerpes carolinus	x						
Melospiza georgiana	x	x	x			x	
Mimus polyglottis	x						
Mycteria americana	x	x	x	x	x	x	x
Nycticorax nycticorax		x		x	x	x	x
Nycticorax violacea		x		x	x	x	x
Pandion haliaetus	x	x	x	x	x	x	
Parula americana			x	x	x	x	x
Passer domesticus	x						
Passerculus sandwichensis	x	x					
Picoides pubescens	x						
Piranga rubra	x						
Pipilo erythrophtalmus	x						
Plegadis falcinellus	x	x					

TABLE 1. Continued.

Species	Created wetland	Freshwater marsh	Hardwood swamp	Sandhills	Flatwoods	Cypress swamp	Hammocks
Podilymbus podiceps	x	x		x	x		x
Poliptila caerulea	x						
Porphyrula martinica		x					
Porzana carolina	x	x					
Progne subis	x						
Protonotaria citrea			x		x	x	x
Quiscalus major	x	x					
Quiscalus quiscula	x						
Rallus elegans		x					
Rallus limicola	x	x					
Regulus calendula	x						
Rostrhamus sociabilis		x					
Sayonrnis phoebe	x						
Scolopax minor					x		x
Seiurus motacilla					x	x	x
Seiurus noveboracensis	x		x		x	x	x
Stelgidopteryx serripennis	x	x	x	x		x	x
Strix varia			x		x	x	x
Tachycineta bicolor	x	x					
Thyrothorus ludovicianus	x		x		x	x	x
Toxostoma rufum	x						
Tringa malanoleuca	x	x					
Troglodytes aedon	x						
Tyrannus tyrannus	x						
Vireo griseus	x						
Wilsonia citrina			x		x	x	x
Zenaidura macroura	x						
Mammals							
Dasypus novemcinctus	x						
Didelphis marsupialis	x						

TABLE 1. Continued.

Species	Created wetland	Freshwater marsh	Hardwood swamp	Sandhills	Flatwoods	Cypress swamp	Hammocks
Felis rufus	x			x	x		x
Lutra canadensis	x	x	x	x	x	x	x
Mustela vison		x	x	x	x	x	x
Myotis subflavus	x	x	x	x	x	x	x
Neofiber alleni	x	x					
Odocoileus virginianus	x	x			x		x
Orozomys palustris	x	x				x	
Procyon lotor	x	x	x	x	x	x	x
Sciurus carolinensis				x			x
Sorex longirostris			x		x	x	x
Sylvilagus palustris	x	x					
Ursus americanus			x	x	x	x	x
Total number of species	103	94	82	88	108	91	102
Similarity with created wetland	—	0.40	0.23	0.25	0.27	0.22	0.25

dispersal distances required of wildlife in this study (potentially 0.1 km to 3 km) negate commonly held theories of dispersal and habitat specificity.

CONCLUSIONS—VRWs proved to be a useful mechanism for assessing wildlife use of a created wetland. Conclusions about the created wetland wildlife community were drawn with confidence because they were based upon actual observations of wildlife occurrence. The VRWs were easily established, and use of the VRWs was rapid and can be easily repeated. The immutable nature of the VRWs would facilitate comparison of the case study wetland with other wetland wildlife communities of the region. And use of the VRWs provided useful information about relative richness, the use of the wetland by upland species, use of the wetland by habitat generalists/specialists, and similarity to other wetland types of the region. VRWs would likely prove to be of comparable value in other assessment situations.

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REVIEW

Edward A. Fernald and Elizabeth D. Purdum (eds), *Water Resources Atlas of Florida,* Institute of Science and Public Affairs, Florida State University, Tallahassee, FL 1998, viii + 312. Price: $49.95 + $7.00 s/h.*

Readers who recall a review of the first atlas (*Florida Scient.* 56: 122) will recall my enthusiasm for the useful compendium of freshwater that displayed all aspects in well-integrated text, maps, graphs, and photographs. It was a source that proved valuable in many ways since 1993. Now, a revised atlas is available that promises to be even more useful. The atlas is divided into four sections: Introduction, Florida's Water Resources (with chapters on weather/climate, groundwater, surface water, natural systems, water use and quality), Management and Regional Diversity (including a history of water management and chapters on the five water management districts), and Issues and Conflicts. Some things haven't changed: Chapters are authored by recognized experts, the cartography and photography are superb, and there is an abundance of useful information. What is new is the update of information—an expansion that includes neighboring watersheds of Georgia and Alabama, the restoration projects about the state, and contemporary issues (El Niños/La Niñas, concerns for global warming, and mercury contamination, among other topics). References are provided at the end of each chapter, and some are as recent as the publication year. This is a valuable book with something for many, and it is strongly recommended.—Dean F. Martin, University of South Florida, Tampa.

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OUTSTANDING STUDENT PAPER AWARDS

Florida Academy of Sciences
1999 Annual Meeting

AGRICULTURAL AND NATURAL RESOURCE SCIENCES

Outstanding Student Paper—Graduate

Ronald S. Tubbs, "Accumulation and distribution of dry matter and plant nutrients in cowpea," (with J.D. Greenwood and R.N. Gallagher).

Doreen A. Clarke, "Stabilization and compositional changes of crab waste during storage," (with O. Onokpise and M. Abazinge).

Honorable Mention—Graduate

Marcus V. Warwell, "Propagation of eastern cottonwood *(Populus deltoides)* green woodcuttings."

Honorable Mention—Graduate

Clifford Louime, "High efficiency in vitro regeneration and genetic transformation in grapes," (with J. Lu).

ANTHROPOLOGICAL SCIENCES

Outstanding Student Paper—Graduate *and* University of Florida Sigma Xi Award

Sybil P. DioNe, "No Nubian knots or nappy locks: discussing the politics of hair among African-American women."

Honorable Mention—Graduate

Alayne Unterberger, "Applied anthropology and social marketing: exploring the relationship through a case study."

MEDICAL SCIENCES

Outstanding Student Paper—Graduate

George Ghobrial, "Isolation of mRNA from Bahia pollen and preparation of a complementary DNA library," (with N. Rodriquez, R. Gennaro, S. Klotz, M. Sweeney and R. White).

Outstanding Student Paper—Undergraduate *and* Florida Institute of Technology Chapter of Sigma Xi Award—Undergraduate

Karine F. Legrand, "Effect of various dihydrofolate reductase inhibitors, used singly and in combination, on in vitro growth of *E. coli,*" (with A. Dhople).

BIOLOGICAL SCIENCES

Outstanding Student Paper—Graduate

William B. Blihovde, "The amphibians and reptiles of the Archie Carr National Wildlife Refuge," (with R.D. Owen and L.M. Ehrhardt).

Honorable Mention—Graduate

Noel V. Rizzutto, "The occurrence of a population of clam shrimp, *Eulimadia diversa* Mattox 1937 (Crustacea, Branchiopoda, Spinicaudata) in a sub-tropical ephemeral pond," (with W.W. Price).

Cara Stallman, "Sediment composition of two tropical coastal freshwater ponds, Macae, RJ, Brazil," (with T.L. Crisman and F.E. Esteves).

Outstanding Student Paper—Undergraduate *and* American Association for the Advancement of Science Award

Michelle J. Rudinsky, "Analysis of sandy beaches in Patagonia," (with C.T. Pastor and D. De Lamo).

Honorable Mention—Undergraduate

Amy L. Long, "The role of a wild bird rehabilitation center in preserving seabirds."

Jennifer A. Michael, "Comparative study on avian utilization of two adjacent water bodies: storm water retention pond and Tampa Bay," (with P.M. Dooris).

ENVIRONMENTAL CHEMISTRY AND CHEMICAL SCIENCES

Outstanding Student Paper—Graduate

Eileen Pérez, "Inhibition of Florida's red tide organism by *Nannochloris eucaryotum,*" (with D.F. Martin).

Outstanding Student Paper—Graduate

Kathleen M. Eastman, "Bioremediation of selenium by selected wetland species," (with R.F. Benson, M.T. Gallardo and D.F. Martin).

Outstanding Student Paper—Undergraduate *and* American Association for the Advancement of Science Award

Edward F. Wilson, "Spinning methyls: computational predictions of molecular conformation in a new class of beta-lactam antibiotics," (with E. Turos).

Honorable Mention—Undergraduate

Jennifer Ascher, "Antibiotics in the Twentieth Century," (with E.T. Carpenter and E. Turos).

Outstanding Poster Presentation—Undergraduate

Rebecca L. Barton, "Effect of cattail (*Typha domingensis*) extracts on selected submerged species," (with M.T. Gallardo, R.L. Barton, M.D. Schoderbock, B.B. Martin and D.F. Martin).

Patrice Rose, "Phytotoxicity of cattail (*Typha domingensis*) mulches," (with M. T. Gallardo and D.F. Martin).

PHYSICS AMD SPACE SCIENCES

Outstanding Student Paper—Undergraduate *and* Florida Institute of Technology Chapter of Sigma Xi Award—Undergraduate

William Junek, "Chemical bath deposited CdS on CIS solar cells," (with J. Underwood and R.P. Raffaelle).

Outstanding Student Paper—Undergraduate

Lori Hall, "On the outskirts of Faraday's Laws," (with T. Beachy and H. Hickman).

Timothy Beachy, "On the outskirts of Faraday's Laws," (with L. Hall and H. Hickman).

FLORIDA COMMITTEE ON RARE AND ENDANGERED PLANTS AND ANIMALS

Outstanding Student Paper—Graduate *and* Central Florida Chapter of the Explorers' Club 1999 Award

Dean Bagley, "Characterization of a population of juvenile green turtles from an east central Florida developmental habitat," (with L.M. Ehrhart).

Outstanding Student Paper—Graduate

Shigetomo Hirama, "Prevalence and severity of the Green Turtle fibropapillomatosis in the Indian River Lagoon," (with L.M. Ehrhart).

Richard M. Herren, "The effect of beach nourishment on marine turtle nesting and reproductive success at Sebastian Inlet, Florida," (with L.M. Ehrhart).

Joseph S. Weidlich, "Historical records of mammals on a newly established National Wildlife refuge in east central Florida," (with L.M. Ehrhardt).

GEOLOGICAL AND HYDROLOGICAL SCIENCES

Outstanding Student Paper—Undergraduate

Monica D. Boland, "Puddle formation in large drops at low Reynolds Number in highly viscous fluids: flow visualization and preliminary characterization of motion," (with E. Shafland, P. Arce, and D. Loper).

Elizabeth R. Shafland, "Puddle formation in large drops at low Reynolds Number in highly viscous fluids: flow visualization and preliminary characterization of motion," (with M.D. Boland, P. Arce, and D. Loper).

SOCIAL SCIENCES

Outstanding Student Paper—Graduate

Amie Haas, "A formula for success: predictive models of retention and arrest for Florida drug court participants," (with R.H. Peters and M.R. Murrin).

Leilani B. Goodmon, "Social anxiety, self-consciousness, and the recall of interpersonal information," (with R. Medlin.)

Outstanding Student Paper—Undergraduate

Aurora Vaca, "Integrating the use of computers into a Great Books/Good Discussion class format," (with H. Reynolds).

—Compiled by Ernest Estevez, Chair, Awards Committee, Mote Marine Laboratory, Sarasota, FL

ACKNOWLEDGMENT OF REVIEWERS

It is a distinct pleasure to acknowledge the cooperation, dedication, expertise, and service of the following persons, who generously contributed their time and experience in reviewing manuscripts for volume 62. Some kindly reviewed more than one manuscript.

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WELCOME

It is with much pleasure that I extend a warm welcome to all participants in the Sixty-third Annual Meeting of the Florida Academy of Sciences. We are fast drawing to the close of a century which has seen technological development of gigantic proportions, at both the microscopic level and the wider scope of outer space - and of course, at all levels in between. New elements are being created; new heavenly bodies are being discovered; interplanetary exploration is underway; and as we meet this year at a venue selected as one of the State's strategic research institutions, we recognize with a deep sense of gratitude, the part played by our members in this era of scientific development. May we seize the opportunity to build on the achievements of the past during the time we spend at the University of South Florida, that the fruits of our efforts will take us into the next century with pride.

Al Hall, President.

MEETING INFORMATION

The 63rd Annual Meeting of the Florida Academy of Sciences will be held at the University of South Florida in Tampa, Florida, March 11-13, 1999. A symposium, "Science in Florida: A Centennial Retrospective," has been planned.

LOCATION

Founded in 1956, USF opened its doors in 1960 to 2000 students. Today, USF is the 13th largest university in the U.S., serving more than 36,000 students, with nearly 200 programs at the undergraduate, master's, specialty and doctoral levels, including the M.D.. Located in the Tampa Bay area, USF is fast becoming the model urban research university for the 21st century. Over the years USF has spawned regional campuses in St. Petersburg, Sarasota, and Lakeland. The Tampa campus encompasses 1,700 acres and houses more than 320 buildings. New buildings have been constructed for the Colleges of Public Health and Engineering; the Departments of Communication and Information Sciences and Mathematics: and the Gus Stavros Center for Free Enterprise and Economic Education, the new Bio-Science facility, and the Knight Oceanographic Institute. Also, USF recently established an intercollegiate football program.

USF is located on Fowler Avenue about three miles west of Interstate 75 and three miles east of Interstate 275, and about 17 miles from Tampa International Airport. Further details about USF and vicinity, including location and campus maps, will be provided in the Program Issue of the *Florida Scientist* (Supplement 1 to Volume 62). This and other relevant information will also be posted on the FAS websites (http://www.cas.usf.edu/FAS) and (http://www.pss.fit.edu/fas).

REGISTRATION

ALL PARTICIPANTS ARE EXPECTED TO REGISTER. Academy members receive the Program Issue by mail in advance, as will non-members who register before February 1st, 1999. Additional Meeting material (including programs for individuals registering after 2/1/99) will be available at the registration desk which will be open in the Physics Building at University of South Florida Thursday afternoon March 11, from 3:00 – 5:30pm, Friday, March 12, 7:30am until 4:00pm, and Saturday, March 13, at 8:30am.

LODGING

No reservation can be made through the Academy. The following hotels agreed to reserve a block of rooms at the special conference rates shown if you identify yourself with the Florida Academy of Sciences.

- La Quinta Inn & Suite-Tampa Busch Garden/USF
  3701 E. Fowler Ave. (next to USF)
  Reservations 1-800-531-5900, confirmation number: 971-04871
  $69.00 single/double (including continental breakfast)

- AmeriSuites
  11408 N. 30th St.
  Reservations 1-800-833-1513
  $79.00 (15 King suites and 10 double suites)

- Embassy Suites-Hotel and Conference Center USF
  3704 Spectrum Blvd. (on USF campus)
  Reservations 1-800-EMBASSY
  $129.00 suites (complementary cooked-to-order breakfast)

- Quality Suites USF
  3001 University Center Dr.
  Reservations: 1-800-SUNSHINE
  $94.00 single/double (complementary happy hour)

The Local Arrangements Committee has information on other lodging within easy driving distance from USF. This information will also be posted on the FAS websites (http://www.cas.usf.edu/FAS) and (http://www.pss.fit.edu/fas) and available by phone at 813-974-2344.

MEALS

The Academy Banquet will be held on Friday evening (March 12) following a reception at the Embassy Suites USF at 6pm. The dinner will be a choice of chicken breast florentine or baked shrimp. Vegetarian or special needs dinners are available on special request. Preregistration for the banquet is suggested; only a limited number of tickets will be available on the day of registration.

Complementary box lunches will be provided at 12:30pm on Friday (March 12) at the Engineering Auditorium. For those who desire it, information on local restaurants within a few minutes drive of USF will be available at the registration desk or on the FAS websites (http://www.cas.usf.edu/FAS) and (http://www.pss.fit.edu/fas).

ACADEMY PLENARY SESSION & BUSINESS MEETING

Dr. Jerald T. Milanich, Curator in Archaeology at the Florida Museum of Natural History, will be present the plenary address in the Engineering Auditorium on Friday (March 12), 1:30 pm, immediately following the business meeting. Dr. Milanich's address is entitled "Laboring in the Fields of the Lord: Spaniards, Indians, Anthropologist and Historians -- a Century of Spanish Mission Studies."

MEDALIST PRESENTATION

Dr. Joseph J. Krzanowski, the 1998 Academy Medalist, will present the Annual Medalist lecture immediately following the Banquet. Dr. Krzanowski is Professor of Pharmacology and Therapeutics at the USF Medical Center. The title of his lecture is "The Science of Easy Breathing: Airways, Asthma and Pharmacology."

FIELD TRIPS

A number of exciting field trips are being arranged for this year's Meeting. The Local Arrangements Committee has tentatively planned outings to the Florida Aquarium, Busch Gardens, Museum of Science and Industry, Lowry Park Zoo, and the Hillsborough River Canoe Outpost. It is anticipated that a nominal fee will be charged for these excursions.

USF Ecological Research Area - a tour of the USF Ecological Research Area has been arranged for Saturday, 9:30 to 11:30 am. USF biologist Dr. Henry Mushinsky, who will act as tour guide, will discuss ongoing ecological and biological research at this field laboratory. Interested participants should meet at the Chemistry Building at 9:00 am. There is no charge.

A variety of other free trips being arranged for registrants include the USF Riverfront Park (canoeing), Lettuce Lake Park (trails and elevated boardwalks), Trout Creek Park (picnicking and canoeing), and the Wilderness Park Offroad Trails (offroad biking). Non-guided field excursions also can be made to the USF Botanical Gardens, USF Pious Museum (geological/mineralogical exhibits), and the TECO Manatee Viewing Center.

Information on these and other field trip opportunities will be provided at the registration desk or posted on the FAS websites (http://www.cas.usf.edu/FAS) and (http://www.pss.fit.edu/fas).

LOCAL ARRANGEMENTS

The Local Arrangements Chair for this Meeting of the Academy is Ron Federspiel of the Department of Chemistry at the University of South Florida (813-974-2344, e-mail: federspi@chuma.cas.usf.edu). He may be consulted for any special meeting needs.

SYMPOSIUM

"Science in Florida: A Centennial Retrospective" is the theme of this year's meeting, and the title of a special plenary symposium for the Florida Junior Academy of Science, to be held Saturday, March 13, 1999 at 10:00am – 11:00am in the ENA Auditorium. Four disciplines have been chosen to represent the Florida history of the development of the physical sciences, biological sciences, social sciences and technology. Illustrated presentations are by Dr. Daryl L. Schrader (St. Petersburg Community College) who will speak about Astronomy; Dr. Ernie Estevez (Mote Marine Laboratory) who will speak about marine biology: Drs. Brian M. DuToit and Leslie Sue Lieberman (University of Florida) who will speak about anthropology; and Dr. J. Richard Newman (Florida Institute of Technology) who will speak about computers and the impact on society. Dr. Lieberman will moderate.

FLORIDA JUNIOR ACADEMY OF SCIENCES ANNUAL COMPETITION

The Florida Academy of Sciences will meet with the Junior Academy this year. As the student division of the FAS, the Florida Junior Academy of Science provides opportunities which encourage growth of our middle and senior high school students in science by allowing them to compete, share and network with other students and adults having common interest throughout Florida. The focus of this "common bond" among participants is their research activities. Annual activities encourage student research, sharing of research in a "real life scientist's" format, and interacting with adult role models. The Florida Junior Academy of Sciences is seeking volunteers to assist in judging and act as section moderators at its meeting, to be held on Saturday afternoon (March 13). The Junior Academy is also seeking individuals to critique research proposals for its "Grant in Aid" program in early November, and to evaluate research papers in early February. Persons interested in participating in this rewarding experience should contact the FJAS Coordinator: Pat Zalo, Junior Academy State Director, 2812 26th Avenue Drive W., Bradenton, FL 34205-3707, telephone: 941-756-4156, e-mail: pzalo@yahoo.com.

COMMERCIAL AND INSTITUTIONAL EXHIBITS

Space is available on a first come-fist served basis for a fee of $75.00. Exhibits by research institutions or programs and others of an informational nature may be given free space. Parties interested in fee or free spaces should contact the Local Arrangements Chair for details.

STUDENT AWARDS

Students presenting papers at the Annual Meeting of the Academy and who are registered for the Meeting may be considered for a number of awards. Details are presented below. Students wishing to be considered for one or more of these awards should identify themselves to Session moderators.

1. Outstanding Student Paper Award - This award is presented by any of the Academy Sections to graduate and/or undergraduate students.

2. American Association for the Advancement of Science Award - This award is presented to one male and one female undergraduate student annually and is a one-year membership in AAAS including the journal, *Science*.

3. Explorer's Club Award - This prize of $300 is awarded for the "most original research paper" furthering the goals of the Club in scientific exploration. The prize is awarded to graduate students and the paper must be presented again at the Explorer's Club banquet in Orlando in May.

4. Sigma Xi Award - The first award, presented by the University of Florida chapter of Sigma Xi, is for $50 and a certificate. The award is presented to graduate students only. The second award is presented by Florida Institute of Technology for the best paper by an FIT student. The award is for $50 and $100 for graduate students and undergraduate students.

5. William W. Behrens, Jr./Florida Institute of Oceanography Award - This $750 prize is awarded by the Florida Institute of Oceanography to an undergraduate or graduate student for the best paper in any area of ocean or marine sciences. A written manuscript is required and must be submitted by February 13, 1999 to: Dr. Ernest D. Estevez, Chairman, FAS Awards Committee, Mote Marine Laboratory, 1600 Ken Thompson Parkway, Sarasota, FL 34236, telephone: 941-338-4441, Please, no facsimile or e-mail submittals.

ANNOUNCEMENTS

YEAR 2000 MEETING: The Annual Meeting for Year 2000 will be held at Florida Institute of Technology, March 9-11, 2000.

PERMANENT OFFICES FOR THE ACADEMY: The FAS office has been located at the Orlando Science Center. The Executive Secretary is Debbie A. Jackson. The address and telephone numbers are shown below.

Florida Academy of Sciences
Orlando Science Center
777 East Princeton St.
Orlando, FL 32803
407-514-2079

FLORIDA ACADEMY OF SCIENCES 1999 ANNUAL MEETING PROGRAM SUMMARY

THURSDAY, MARCH 11

TIME	EVENT
3:00 PM	FAS Council Meeting
3:00 PM - 5:30 PM	Registration, Physics Building

continued, next page

FAS MEETING SUMMARY, continued

FRIDAY, MARCH 12

TIME	EVENT
7:30 AM - 4:00 PM	FAS Registration & Information Desk, Physics Building
8:00 AM - 12:30 PM	FAS Concurrent Paper Sessions, Physics Building, Various Rooms
12:30 PM – 2:15 PM	Box Lunches, Business Meeting & Gale Plenary Address, Engineering Auditorium
2:30 PM – 5:00 PM	FAS Concurrent Paper Sessions, Physics Building, Various Rooms
6:00 PM – 7:00 PM	Reception, Embassy Suites Atrium (cash bar)
7:00 PM – 10:00 PM	FAS Banquet & Medalist Lecture, Embassy Suites

SATURDAY, MARCH 13

TIME	EVENT
8:30 AM – 12:00 PM	FAS Registration & Information Desk, Physics Building
8:30 AM - 12:00 PM	FAS Concurrent Paper Sessions, Physics Building, Various Rooms
9:30 AM - 11:30 AM	Tour of the USF Ecological Research Area
10:00 AM – 11:00 AM	Symposium: Science in Florida: A Centennial Retrospective, Engineering Auditorium
12:00 PM	Lunch on your own at local restaurants (information at Registration Desk)
AFTERNOON	Trips to various local attraction (information at Registration Desk)

AGRICULTURAL AND NATURAL RESOURCE SCIENCES

FRIDAY, 2:30 PM PHYSICS 120
SESSION A
OGHENEKOME ONOKPISE, FLORIDA A&M UNIVERSITY, presiding

2:30 PM AGR-1 Stabilization and Compositional Changes of Crab Waste During Storage. D. A. Clarke, O. U. Onokpise, and M. Abazinge, Florida A& M University, Tallahassee, Florida 32307. Crabmeat production is very important to the economy of Florida. However, the disposal of the waste from the production of crabmeat has become a serious environmental problem. Crab waste causes odor and nitrate pollution problems especially to the ground water systems. A preliminary investigation into the stabilization of crab waste was undertaken using chemical and molasses. Experimental design was a split plot with chemicals randomized within parts of the crab waste. Preliminary results indicate that of the five chemicals used, Fomaldehyde and Hydrogen Peroxide were the most effective at stabilizing the crab waste. Observations were made mainly for texture and color. Untreated samples were the first to deteriorate especially the meaty portions. Legs, eggs and shells took the longest time to show any changes.

2:45 PM AGR-2 Cogongrass (Imperata cylindrica L.) Populations in North Florida and Southeast Alabama. O. U. Onokpise (1), G. Bolfrey-Arku (2), D. Shilling (3), and C. Coultas (1), Florida A&M University, Tallahassee, Florida 32307 (2) Crops Research Institute, Kumasi, Ghana, (3) University of Florida, Milton Campus, Florida 32572. Congograss has been identified as a significant exotic weed problem in Florida and other Gulf States. Yet its actual population and sites in these states have not been fully documented. A survey of three counties in North Florida and one in Southeast Alabama was conducted in order to establish areas for biological control experiments. Results indicated that Leon County in Florida had the most cogongrass, while Mobile County in Alabama ranked second, and Gadsden and Jefferson Counties of Florida ranked third and fourth respectively. Roadways were the most widely infested compared to farm sites and forest ecosystems. It is speculated that cogongrass may have been introduced through one of the seaports in Alabama. Its distribution may be occurring through the railway system, and movement of soils during road construction.

3:00 PM AGR-3 Woody Biomass Production in Phytoremediation Systems. D. L. Rockwood (1), G. R. Alker (1), L. Q. MA (2), and K. Komar (2), (1) School of Forest Resources and Conservation (2), Department of Soils and Water Sciences, University of Florida, Gainesville, FL, USA

32611. Woody Biomass production for energy and other uses can be desirably enhanced while concurrently removing contaminants from soil and water. An interdisciplinary study with goals of 1) identifying the most effective tree genotypes for chemical/metal uptake, 2) quantifying their phytoremediation potential, 3) developing guidelines for establishing and managing phytoremediation systems using these genotypes, and 4) exploring environmentally benign uses of the woody Biomass produced in these systems and involving a number of field sites has assessed growth and phytoremediation potential of castorbean, cottonwood, cypress, Eucalyptus amplifolia, E. camaldulensis, E. grandis, Leucaena leucocephala, and several other species for a range of applications. Complementary studies have also screened laurel cherry, red maple, sweetgum, sycamore, yellow poplar, and numerous herbs, shrubs, and grasses for As, Cr, and Cu uptake.

3:15 PM AGR-4 Propagation of Eastern Cottonwood (Populus deltiodes) Green Woodcuttings. M. V. Warwell. University of Florida, School of Forest Resource and Conservation, P.O. Box 110410, 118, Newin-Ziegler Hall, Gainesville, FL. 32611. Cottonwood cuttings derived from seedlings collected from the U.S. Southeastern region are examined for variation in rooting performance based on genetic and physiological differences. Cultural techniques, including testing rooting response to application of exogenous hormones (indolebutyric acid (IBA), naphthalene acetic acid (NAA), and ethephon) are also examined. Clones are then inoculated with Agrobacterium to examine variation in response to increase levels of endogenous auxin.

3:30 PM AGR-5 Pasture Mole Crickets in Central Florida: Overview of Origin, Ecological Impact and Biological Control. M.B. ADJEI. University of Florida, Range Cattle REC, Ona, FL 33865-9706. The most important insect pest of lawn and pasture in southeast USA are Scapteriscus molecrickets. Introduced accidentally to the USA in ship's ballast from South America around 1900, mole cricketshave engaged the attention of Florida cattlemen as long as they can remember. Withdrawal of long-lasting chemicals from the market by the EPA and the recent pest outbreaks on pasture have created renewed urgency for effective biological remedies. The history, ecological impact, and progress on alternative of/for mole crickets are examined. In vivo production of the mole cricket nematode (Steinernma scapterisci) and distribution of nematode on pasture through infected mole crickets are detailed.

3:45 PM BREAK

4:00 PM AGR-6 Accumulation and Distribution of Dry Matter and Plant Nutrients in Cowpea. R.S. TUBBS (1), J.D. GREENWOOD (20, AND R.N. GALLAHER (2). (1)Agric and Biol. Engineering and (2) Agronomy, Inst. Food & Agri. Sci., University of Florida, Gainesville, Fl. 32611. The objective of this study was to determine the nutrient accumulation and dry matter (DM) distribution within the leaves, stems, pods, and roots of 'White Acre' cowpea (Vigna unguiculata) over a period of 91 days. A completely randomized design with four replications was used. Plant samples from an area of 1m2 were taken every 7 Days, beginning 14 days after planting (DAP). Nutrient concentrations were determined by the modified micro-Kjedahl procedure for N, atomic absorption spectrometry for Ca, Mg, Fe, Mn, Zn, and Cu, atomic emission spectrometry for Na and K, and colorimetry for P. Data from this experiment showed that all nutrient concentrations in diagnostic leaf tissue are at or above sufficiency levels except for Ca being a little low and K bordering on the sufficiency range. Calcium and Mn showed traits of being immobile while all other nutrients displayed a trend of at least some mobility. Dry matter accumulation peaked at 77 DAP for the whole plant (658 g m-2) and the leaves and stems followed a similar pattern as the total plant, but peaked earlier due to the onset of pods. Vegetative growth slowed as the reproductive part of the plant started to mature. Pods continued to grow until end of the study at 91 DAP, even though the plant started to lose DM and most nutrients after around 70 DAP.

4:15 PM AGR-7 Analyzing the Impact of Inflation on Wine Consumption in Florida, 1970-1995. Stephen Leong and Shenetra Duffie, College of Engineering Sciences, Technology and Agriculture, Florida A&M University, Tallahassee, Florida 32307. The study looked at how price and income, during two different inflationary periods, affects wine consumption in Florida. The affect of price inflation on the rate of wine consumption was analyzed using a single-equation regression model with the rate of wine consumption as the dependant variable, and price and income as the independent variables. Two periods were defined by using a dummy variable. Period one is when the increase in the rate of price inflation for wine is greater than the increase in general rate of price inflation for other goods and services between 1970-1995, and Period 2 is the reverse. The model was estimated using Maximum Likelihood technique after correcting for autocorrelation. As hypothesized, price inflation did not have a significant impact on the rate of wine consumption in Florida between the two periods. The results suggest that wine consumption may becoming more popular and acceptable as a beverage at meals and social functions due to changing lifestyles and less sensitive to inflationary forces in the market.

4:30 PM AGR-8 Influence of Time and Sequential Application of Glyphosate Efficacy in the Control of Imperata cylindrica L., G. BOLFREY-ARKU (1), O.U. ONOKPISE (2), D. SHILLING (3), AND COULTAS (2), (1) Crops Research Institute. Kumasi, Ghana, (2) Florida A&M Universty, Tallahassee, Florida. 32307, (3) University of Florida, Milton Campus, Florida 32572. Speargrass (Imperata cylindrica L) is a major constraint of food production in Ghana. It affects over 50% of the farms in the Forest-Savanna zone of this tropical region. As part of the overall project on the control of this noxious weed, a study was undertaken to determine the influence of time and sequential application on glyphosate efficacy. The study was a randomized complete block design in four replications, with plot sizes set at 6m x 6m. Treatments were early (March), middle (June), and late (September), and their combinations. There was no significant difference in percentage speargrass kill at 4 weeks after treatment (WAT), or shoot biomass (dry weight) at 9 WAT. Shoot densities (number of speargrass plants per m squared) were highest for plots treated in June with a follow-up in September. Shoot growth was similar for June and September applications at 9 WAT.

4:45 PM AGR-9 Alternative Crops for Forage. R.N. GALLAHER, Agronomy Department, University of Florida, Gainesville, 32611. Florida dairy products are in need of year-round supply of high quality forage. The objective of this research was to conduct preliminary investigations on the forage yield and quality potential of alternative forage crops. Summer experiments tested no-tillage planting rates of soybean (Glycine Max) and cowpea (Vigna unguiculata) for yield and forage quality. Fall experiments tested no-tillage cowpea varieties and conventional tillage soybean, cowpea, collard, turnip, and mustard varieties for forage yield and quality potential. The fall planted soybean variety experiment tested varieties at three-row spacing. High population and narrow rows of early summer planted no-tillage soybean and cowpea resulted in best weed competition and hay yields of over 5,000 kg/ha. Crude protein was about the same for both crops (12.1 to 12.3%). Whole plant dry matter yields from fall planted no-till cowpea ranged from 4400kg/ha for 'Cream 12' to over 5500kg/ha for "California Blackeye". Highest yield of fall conventional planted soybean was from narrow rows (0.25 m wide) and University of Florida experimental Long-Juvenile trait varieties. When harvested at the R6 stage of growth it was estimated that some varieties would produce silage yields up to 30,000kg/ha when planted in narrow rows. Varieties of turnip (Brassica rapa), mustard (Brassica juncea and B. Perviridis) and collards (Brassica oleracea) were found that produce top dry weight yields of from 4500 to over 5000kg/ha.

SATURDAY, 10:00 AM PHYSICS 120
SESSION B
OGHENEKOME ONOKPISE, FLORIDA A&M UNIVERSITY, presiding

10:00 AM AGR-10 Effect of Supplemental Nitrogen Fertilizer on No-Tillage Tobacco Following a Simulated Excessive Rainfall Event. J.D. GREENWOOD (1), R.S.TUBBS (2), R.N. GALLAHER (1), AND E.B. WHITTY (1), (1) Dept. of Agronomy, (2) Dept. of Agriculture and Biological Engineering, Inst. of Food and Agricultural Sciences, University of Florida, Gainesville 32611. The efficient management of N fertilizer in crop production is necessary to produce optimal yields as well as to decrease the potential or groundwater contamination by nitrates. The objective of this study was to determine the effect of supplemental N rates on yield, mineral concentration and content and soil properties following a simulated rainfall event on no-tillage tobacco (Nicotiana tabacum). Tobacco leaves were analyzed for N concentration using the modified microKjeldahl N procedure. Concentrations of Ca, Mg, Fe, Mn, Zn, and Cu were analyzed by atomic absorption spectrometry. Sodium and K were analyzed by atomic emission spectrometry and P by colorimetry. The addition of 50 lb. N/acre was found to increase dry matter yield by 21% over the control and is thought to compensate for the effect of N leaching. The N concentration in the top, middle, and lower leaves increased by 55%, 53%, and 86% respectively. Addition of N decreased K concentration in the top leaves. It is estimated that a supplementary application of 50lb. N/acre after an excessive rainfall event of 3.5 acre inches, more or less, will increase profit by approximately $388/acre for flue-cured tobacco in Florida.

10:15 AM AGR-11 Using Cover Crops to Recycle Nitrate (NO3)- N following Staked Tomato Production in North Florida. C.S. GARDNER, O.S. MBUYA and G.L. QUEELEY. Div. of Agric. Sciences, Florida A&M University, Tallahassee, Florida 32307. On sandy soils residual NO3-N from fertilizers applied to staked tomato may leach to contaminate groundwater. An on-farm study was conducted in north Florida, to evaluate the uptake of residual NO3-N by cool and warm, season grass and legume species grown as cover crops. Crop species included ryegrass (Lolium multiflorum), oats (Avena sativa), Crimson clover (Trifolium incaratum), Hairy vetch (Vicia villosa), Pearl millet (Pennisetum glaucum), Sorghum Sudan grass (Sorghum bicolor), Iron clay pea (Vigna sp) and Joint vetch (Aschenomene). To provide baseliine data, soil samples were taken at depths of 0-30, 30-60 and 60-90 cm prior to planting the cover crops. Biomass samples of the cover and soil samples were taken during the crop growth period to determine tissue N content and soil N movement. A randomized complete block design with four replications was used for the study. Results showed residual soil N of up to 250 kg ha-1 at 90 cm depth. Soil N uptake in the (cool season) grass crops average 168 kg ha-1

10:30 AM AGR-12 Evaluation of Composition of Crab Processing Waste from Crawfordville, FL. A. BERZAT M.D. ABAZINGE AND O. U. ONOKPISE, Florida A&M University, Tallahassee, FL. 32307. The practice of dumping wastes from blue crab processing plants into landfills has created numerous landfill and enviromental quality problems here in Florida. Crab waste samples were collected from Metcafe Crabbintg Company in Crawfordville, FL. Proximate analysis was performed for different parts of the crab waste. The sections included legs, eggs, shells, and the meaty portions. Moisture and dry matter contents percentages were generally higher in the meaty portions of the crab. A higher percentage of crude protein was obtained when using a digestion acid volume of 30ml.

10:45 AM AGR-13 High Efficiency in vitro Regeneration and Genetic Transformation in Grapes. C. LOUIME AND J. LU, Center For Viticultural Sciences, Florida A&M University, Tallahassee, Fl 32307. The alternative, and potentially less time-consuming approach of gene transfer to insert desirable traits is particularly promising for grape, even considering the time necessary for field testing transgenic lines. Successful genetic transformation requires the optimization of several factors that include in vitro culture system, methods of gene transfer and the expression of the introduced gene in plant tissue. The objective of the study was to develop an efficient and reliable tissue culture system for high frequency plant regeneration including induction of callus and somatic embryos from leaves, petioles, tendrils of grape cultivar Orlando Seedless most promising bunch grape in southeastern United States. Those tissues were cultured on several growth media with different hormone concentration. Data from this experiment indicate that petiole plated on Nitsch and Nitsch medium is the most effective medium at regenerating plantlets. There were no somatic embryos formed, when callus derived from petioles were transferred to growth medium.

11:00 AM AGR-14 A survey of Internet-Based Distant Learning Courses in Agriculture. Z. I. Olorunnipa. Agribusiness Program, Florida A&M University, Tallahassee, 32307. The World Wide Web continues to revolutionize the way business is done in almost all sectors of the economy. In higher education, this information technology has diversified pedagogic instructional delivery process. While some colleges of agriculture already have several on-line courses available, others are yet to adopt the innovation for various reasons. In terms of web-based agriculture courses a comprehensive inventory of who offers what is not yet available to the best knowledge of this author. This study is designed to fill this vacuum in knowledge. The methodological approach involves a combination of using search engines and survey questionnaires to identify current on-line agriculture courses, their originators and enrollment requirements. In addition, the pros and cons of offering agriculture classes via on-line are examined.

SATURDAY, 11:15 AM PHYSICS 120
BUSINESS MEETING: AGRICULTURAL AND NATURAL RESOURCE SCIENCES
OGHENEKOME ONOKPISE, presiding

ANTHROPOLOGICAL SCIENCES

SATURDAY, 9:00 AM PHYSICS 141
KAREN WALKER, UNIVERSITY OF FLORIDA, presiding

9:00 AM ANT-1 Microliths and Shell Bead Production at the Narvaez/Anderson Site, Pinellas County, Florida. ROBERT J. AUSTIN, Southeastern Archaeological Research, Inc., P.O. Box 2818, Riverview, FL 33568. Recent test excavations at the Narvaez/Anderson site, a late prehistoric and protohistoric (ca. A.D. 1000-1600), Safety Harbor culture, shell mound and midden complex on Boca Ciega Bay in Pinellas County, resulted in the recovery of numerous stone artifacts and waste debris from their manufacture and maintenance. This paper presents the results of a technological and functional analysis of these artifacts. A dominant activity represented by the stone tool assemblage was the use of microliths to drill shell, and perhaps to manufacture shell beads. The stratigraphic and spatial isolation of this assemblage within the Narvaez/Anderson site suggests that it may represent the presence of craft specialists. I discuss the implications that such an interpretation has for the study of emergent Safety Harbor political economy, and for the role of craft specialization in the development of complex societies generally.

9:15 AM ANT-2 Historical trends and methods in the zooarchaeology of fish remains: Incorporating a fisheries biology perspective. PATRICK O'DAY, AND SHARYN JONES O'DAY. University of Florida Dept. of Anthropology, 1350 Turlington Hall, Gainesville 32611. Changes in collection methods, and in the goals of interpreting faunal remains are discussed with an emphasis on previous research in the southeast U.S. We also look at current techniques used in the analysis of fish remains, including investigation of aging structures. Otolith analysis in archaeology is specifically discussed. We propose that analysis of fish remains can be improved upon by rigorously incorporating techniques commonly used in fisheries and marine biology. Current research in Maui, Hawaii is presented as an example in which research incorporates the biological technique of an ecological survey of a coastal marine environment. Finally, the authors present prospective research on aging structures in fish remains.

9:30 AM ANT-3 Morphological Evidence of Health Status among Three Florida Archaic Sites. H.A. WALSH-HANEY, University of Florida, P.O. Box 112545 Gainesville, 32611. The skeletal remains from the early Archaic site of Windover (8BR246), middle Archaic site of Bay West (8CR200) and late Archaic site of Bird Island are evaluated through bioanthropological analysis in order to reconstruct the health of these populations. Specifically, skeletal markers of physiological stress and diet, such as cribra orbitalia, porotic hyperostosis, antemortem trauma, linear enamel hypoplasia, dental caries, dental attrition, periostitis, and osteoarthritis are presented. The differences and similarities between these Archaic populations are discussed and related to hypothesized differences in resource abundance and quality, settlement patterns, and parasite load.

9:45 AM ANT-4 Calusa Survival. A.L. SNAPP. University of Oxford, School of Anthropology and Museum Ethnography. Pitt Rivers Museum, South Parks Road, Oxford OX1 3PP, England. The Calusa Indians of the Southwest Florida coast survived as a distinct culture for nearly two centuries following official European Contact in 1566. This cultural continuity contrasts with the native cultures in North Florida which crumbled under the Spanish mission system. Factors involved in maintaining Calusa cultural continuity are examined. Beginning with the open hostility of the Calusa towards the Spanish, a portrait is presented of a culture that through Spanish policy, the Calusa power structure, isolation, and perhaps a trade relationship continued to assert itself as an independent nation. The end of the Calusa culture occurs with the extinction of a people in the mid-18th century.

10:00 AM ANT-5 A Local Shift in Shellfish Availability During the Medieval Optimum Period: Environmental Archaeology on Southwest Florida's Useppa Island. K. J. WALKER, Florida Museum of Natural History, PO Box 117800, University of Florida, Gainesville, FL 32611. Archaeological molluscan shell assemblages from various precolumbian time periods are compared: all assemblages are from one estuarine location, Southwest Florida's Useppa Island. The assemblages document a dramatic shift in shellfish availability that occurred during the ninth and tenth centuries A.D. Explanatory factors are explored, including inlet dynamics and sea-level change. The temporal correlation between the shellfish shift and the climatic warming trend known as the Medieval Optimum is considered.

10:15 AM ANT-6 Singing Our Way to Environmental Understanding?: Can Alternate Ecological Presentations Make A Difference? BARBARA E. ROTHSTEIN, PH.D. DOUGLAS STUTZ, PH.D., AND MARK GOTTFRIED, PH.D. Biomedical and Environmental Advancement Magnet (BEAM), Miami Dade Community College School of Environmental and Fire Science, BEAM, North Miami Beach Senior High School, 1247 NE 167th Street, North Miami Beach, Florida 33162. An Environmental expert and folk singer presented environmental information to students at the high school and college levels. The investigators employed pre and post-performance questionnaires to study attitudinal and informational changes.

10:30 AM BREAK

10:45 AM ANT-7 No Nubian Knots or Nappy Locks: Discussing the Politics of Hair Among African-American Women, SYBIL DIONE, Dept. of Anthropology, University of Florida 1112 Turlington Hall P.O. Box 117305 Gainesville, 32611. American culture primarily relies on a standard of beauty that is conveyed through the media. However, this standard of beauty tends to be disproportionately centered on European physical features. This reality creates a paradox for the African-American woman. The media transmits a subtle message that African features are undesirable, skin that is too dark is not acceptable, and kinky hair is not attractive. Since there is currently no feasible means of significantly lightening skin and plastic surgery is costly the majority of African-American women resort to controlling and changing the natural texture of their hair in a subconscious effort to affirm their overall physical attractiveness. Through interviews, participant observation, and content analysis of media I explore the ways in which African-American women attempt to symbolically regain social power through the manipulation of their hair and hairstyles.

11:00 AM ANT-8 Applied Anthropology and Social Marketing: Exploring the Relationship Through A Case Study. ALAYNE UNTERBERGER, Department of Anthropology, University of Florida, Turlington Hall, Room 1350, Gainesville, Fl. 32612 . Applied anthropologists work in a variety of settings and often join multi-disciplinary teams to plan, design, research, or evaluate programs. Anthropology and anthropological contributions to international development often downplay the role of marketing, even if the development program did utilize marketing. This session explores the concept of social marketing, its methodologies and applications within the context of contemporary anthropological theory and practice. A case study of an on-going health-related social marketing program aimed at encouraging the use of family planning for Mexican farmworker males (entitled ¡Pocos Hijos Para Darles Más!) will be utilized to examine whether or not this approach is congruent with contemporary applied anthropology.

11:15 AM ANT-9 Becoming a "Native" Anthropologist: Confronting Issues of Epistemology and Methodology in Emic Research, SYBIL DIONE, Dept. of Anthropology, Univ. of Florida 1112 Turlington Hall P.O. Box 117305 Gainesville 32611. Anthropology has traditionally been concerned with investigating pre-literate and non-industrial societies. This tradition involved researchers stepping outside of their own cultural boundaries to embrace the culture of the "other." However, anthropology is experiencing a metamorphosis because of the influx of the "other" into academia. Occasionally, this de-colonization of the discipline positions researchers in complex and literate societies where they may also be members. This repositioning has given rise to a phenomenon called "native" anthropology, which involves researchers investigating their own cultures. However, despite this repositioning of the anthropological lens classical terms, methods, and theories have remained unchanged. Therefore, this writing challenges some of the assumptions surrounding the definition of a "native" and then offers some suggestions towards the formation of a "native" perspective in anthropology.

11:30 AM ANT-10 The Trenner Site: An Inquiry into Manasota Cultural Traditions. John Whitaker and Dan Hughes , Janus Research, 2935 1st Ave. N. St. Petersburg 33713. In May of 1998, a Phase I and II archaeological investigation of the proposed St. Joseph's Sound Condominiums development area was conducted by Janus Research. The survey resulted in the confirmation of a previously recorded archaeological site known as the Trenner Site (8PI2250). The site consists of a black dirt midden containing ceramic sherds, bone tools, and a dense concentration of faunal remains. The presence of decorated Weeden Island, Sand-tempered Plain, and Pasco plain ceramics indicated that the site was associated with the prehistoric Manasota cultural tradition (ca. 500 B.C. to A.D. 900). Shovel testing conducted during the survey indicated that much of the midden was undisturbed. In addition, the large volume of faunal material that was recovered indicated that the potential for additional research related to Manasota subsistence was high. The purpose of this paper is three-fold. The first purpose is to summarize past assumptions about Manasota culture. The second is to examine where the Trenner site sits within the current understanding of the Manasota. The third is to discover what new questions can be asked in the future based on the information obtained from the Trenner Site.

11:45 AM BUSINESS MEETING: ANTHROPOLOGICAL SCIENCES
KAREN WALKER, presiding

BIOLOGICAL SCIENCES

FRIDAY, 8:30 AM PHYSICS 141
JEREMY MONTAGUE, BARRY UNIVERSITY, presiding

8:30 AM BIO-1 MtDNA analysis of a hybrid zone in *Fundulus majalis* in a northeastern Florida ecotone. C.F. DUGGINS, JR. (1), K. RELYEA (2), J.A. BREMER (1), (1) Dept. Biological Sciences, Univ. South Carolina, Columbia, SC 29208, (2) Biology Dept., Armstrong Atlantic State Univ., Savannah, GA 31419. *Fundulus majalis*, the Striped Killifish, occurs from New Hampshire to Tampico, Mexico with an ecological hybrid zone in northeastern Florida. Analysis of the mtDNA control region I revealed a northern and southern clade on the respective ends of the hybrid zone with a narrow (10km) region where mitotypes of one clade are clinally replaced by the mitotypes of the other, supporting the hypothesis that *F. majalis* was recently composed of two allopatric populations which have since recontacted. In addition, we obtained mitotype frequencies at 5 localities within the hybrid zone every two months for two years and found no significant temporal variation and therefore no evidence of migration.

8:45 AM BIO-2 Growth factors and ovarian peptides as modulators of oocyte maturation. Y.–W.P. LIN, T.M. SMITH, R. ROBERTS, T.R. PETRINO. Barry University, 11300 NE 2nd Avenue, Miami Shores, FL 33161. In addition to steroid hormones, several growth factors and related peptides are present in the gonads, whose potential roles as local modulators of ovarian function are not yet clearly defined. In this study, we have examined the effects of various growth factors, activin, and inhibin in the process of germinal vesicle breakdown (GBVD) or oocyte maturation using amphibian fully grown preovulatory ovarian follicles cultured in vitro. Inhibin blocked GBVD initiated by exogenously added Progesterone (the physiological inducer of GVBD) in intact as well as in denuded oocytes. Activin stimulated GBVD and enhanced the progesterone-induced oocyte maturation. Epidermal growth factor alone has no effect on GBVD, but enhanced the progesterone-induced oocyte maturation. Taken together data from this study presents evidence that growth factors and related gonadal peptides may be relevant modulators of oocyte maturation. (Supported by NIH-NIGMS MARC Grant, GM08021-15 and MBRS Grant, GM 45455-07, Barry University).

9:00 AM BIO-3 Molecular characterization of carbonic cnhydrase from the mosquito *Aedes Aegypti* . EMMANUEL JEAN-JACQUES (1), PAUL LINSER (2), ZHENPENG ZHUANG (1), (1) SNHS-Biology, Barry University, 11300 NE 2nd Avenue, Miami Shores, FL 33161, (2) University of Florida, Whitney Laboratory, St. Augustine, FL. The mosquito *Aedes aegypti* is a host for many parasites and nation-wide Anti-*Aedes aegypti* campaigns intend to eradicate the species. This *A. aegypti* larva has high alkalinity in its midgut to breakdown tannins (tannic acid) derived from plant food. This high alkalinity is due to the presence of a carbonic anhydrase (CA). The goal of this study was to isolate and localize the CA gene in *A. aegypti*. CA primers were designed using a *Drosophila* CA gene sequence. The primers were used in PCR in an attempt to isolate the CA gene cDNA. A 300bp band, which was observed, was approximately the expected length of the desired gene. The 300bp cDNA was isolated and sequenced. After sequencing the 300bp band and comparing it to ' Gene Data Bank' sequences we concluded that the gene sequence isolated was not the CA gene. This is most likely due to technical difficulties during the PCR procedure. However, continuation of this study will result in a successful isolation of a clone for CA. This will lead to designing of inhibitory strategies to eliminate *A. aegypti*. (Supported by NIH-NIGMS MBRS Grant GM 45455, Barry University.)

9:15 AM BIO-4 Analyses of ash-free (mineral) dry-weight and soluble protein in the seagrasses *Thalassia testudinum* and *Syringodium filiforme*. J.R. MONTAGUE (1), K. REIN (2), T. PODONA (2), J.C. LOPEZ (1), SNHS, Barry University 11300 NE 2nd Avenue, Miami Shores, FL 33161, (2) Chemistry Department, Florida International University, Miami, FL 33199. As part of a continuing study of the ecological relationship between tropical seagrasses and herbivorous sea urchins, green and decayed (fully-necrotic) tissues from the leaves of the seagrasses *Thalassia testudinum* and *Syringodium filiforme* were compared for mean dry weight ($\text{decayed}_{Thal} > \text{green}_{Thal}$, $\text{decayed}_{Syri} < \text{green}_{Syri}$) and mean ash-free (mineral-content) dry weight ($\text{decayed}_{Thal} < \text{green}_{Thal}$, $\text{decayed}_{Syri} > \text{green}_{Syri}$). Dried tissue samples were homogenized in 0.5% Tritonex, and soluble protein concentration was determined by BSA (Bovine Serum Albumin) standard addition and spectral analysis. The mean soluble protein was calculated as %-dry weight (for both species decayed = green = 8-12%). The green *T. testudinum* tissue contained proportionally much more mineralized material (probably silicates) and much less organic material than the decayed *T. testudinum* tissue, though the two tissues were roughly equal in free protein content. (Supported by NIH-NIGMS MBRS Grant GM 45455 to Barry University and NIEHS Grant to FIU).

9:30 AM BIO-5 The amphibians and reptiles of the Archie Carr National Wildlife Refuge. W.B. BLIHOVDE (1), R.D. OWEN (2), L.M. EHRHART (1), (1) University of Central Florida, Department of Biology, 4000 Central Florida Blvd., Orlando, Florida 32816-2368, (2) Florida Museum of Natural History, University of Florida, PO Box 117800, Gainesville, Florida 32611-7800. The Archie Carr National Wildlife Refuge (ACNWR) is located entirely on the system of barrier islands that line the Atlantic coast of Brevard and Indian River Counties. The ACNWR was established as a refuge for marine turtles that nest on the endangered beaches. For over a decade the University of Central Florida Marine Turtle Research Group (UCFMTRG) has kept detailed species lists for the ACNWR and surrounding areas. Starting in 1996 the UCFMTRG has monitored the relative species abundance and species diversity of a small coastal community in the ACNWR. Drift fences, herp arrays, coverboards, and visual surveys were used to capture herptiles in several habitat types. Forty-three species of herptiles have been documented including the species of marine turtles that nest at the ACNWR. *Cnemidophorus sexlineatus* and *Gastrophryne carolinensis* had the highest relative abundance during the three years of study. Along with UCFMTRG's general observations, quantitative monitoring methods will help determine the herpetological diversity of the island.

9:45 AM BIO-6 Biological monitoring on Seminole County Natural Lands. W.B. BLIHOVDE, University of Central Florida, Dep artment of Biology, 4000 Central Florida Blvd., Orlando, FL 32816-2368 and Seminole County Natural Lands Program, Seminole County Government, Planning and Development Department, 1101 East First Street, Sanford, Florida 32771. Seminole County Natural Lands Program (SCNLP) was formed in 1990 to preserve and protect natural lands for Seminole County citizens. SCNLP has purchased over 4000 acres on seven different properties. A systematic biological monitoring program was initiated in 1998 to quantify the significant trends that occur in species richness and abundance. Invertebrates, plants, and vertebrates are monitored quarterly to enumerate baseline data and insure that land management is done accurately. The effects of prescribed fires are also closely monitored with pre- and post-fire surveys. In the first year of biological monitoring at Seminole County an annual monitoring schedule was developed to make monitoring systematic. The monitoring methods used by SCNLP will be detailed, including information on the importance of the monitoring data to agencies and the public. Several important species have been discovered due to this important monitoring program.

10:00 AM BREAK

10:15 AM BIO-7 Spatial distribution of benthic macroinvertebrates in Boca Ciega Bay. DAVID J. KARLEN (1), ERIC M. LESNETT (1), NANCY M. PAGE (2), (1) Environmental Protection Commission of Hillsborough County, 1410 N. 21st. Street Tampa 33605, (2) Pinellas County Department of Environmental Management, 300 S. Garden Ave., Clearwater 33756. Benthic grab samples have been collected annually from Boca Ciega Bay since 1995 as part of the Tampa Bay National Estuaries Program's bay wide benthic monitoring program. For the first three years of sampling (1995-1997) results have shown that the dominant infaunal taxa vary in spatial distribution among the sampling sites, with fewer than 3% of over 300 taxa occurring at 50% or more of the stations in any given year. Additionally, more than 40% of the taxa were present at only a single location. This heterogeneous distribution is examined in relation to habitat type, physical conditions, and sediment quality.

10:30 AM BIO-8 The occurrence of a population of clam shrimp, *Eulimnadia diversa* Mattox 1937 (Crustacea, Branchiopoda, Spinicaudata) in a sub-tropical ephemeral pond. N.V. RIZZUTTO (1), W.W. PRICE (2), (1) University of South Florida, Dept. of Biology, 4202 E. Fowler Ave. Tampa 33620, (2) University of Tampa, 401 W. Kennedy Blvd. Tampa 33606. *E. diversa* is reported for the first time in Florida; a population was found in a pond near downtown Tampa. Collections were made on seven occasions concomitant with rains from March through November, 1998. During these samplings, temperature and pH ranged from 29.0 to 43C and 7.6 to 8.2, respectively. During the longest hydration period in July (20 days, 29.0 – 37.1C) the majority of larval stages were completed by day 3, the postlarval stages by day 8. Egg carrying females first appeared on day 5 (1 individual) and by day 8, over 76% of the adults carried eggs. Average clutch size was 160 eggs female^{-1} (range: 96 – 246). Growth through the larval and postlarval stages was achieved at a rate of 0.67mm day^{-1}. Adults continued to grow for another 2 days, at a rate of 0.09mm day^{-1} and then dropped to 0.05mm day^{-1} over the next 7 days. Only females were collected, as males have not yet been observed in samples. This implies a non-sexually reproducing population of *E. diversa*. Parthenogenesis and selfing hermaphroditism have been reported and implied, respectively, for other members of *Eulimnadia*.

10:45 AM BIO-9 Analysis of sandy beaches in Patagonia. MICHELLE J. RUDINSKY (1), CATALINA T. PASTOR (2), and DANIEL DE LAMO (2). (1) SNHS-Biology, Barry University, 11300 NE 2nd Avenue, Miami Shores, FL 33161, (2) Centro Nacional Patagonico, 9120 Puerto Madryn, Chubut, Agentina. On sandy beaches, most invertebrate phyla are represented as members of the meiofauna, macrofauna or both. The macrofauna include representatives of all major taxa, although polychaete worms, molluscs and crustaceans predominate. The objective of this investigation was to compare the organisms found at two different beaches and see how animal distribution was affected by various physical and chemical factors. Samples were obtained by digging. Sand was removed, filtered and remaining matter was collected in plastic bags. In the lab, samples were sorted and classified. Overall, fewer organisms were found than expected. This may be attributed to time of year, and strange weather patterns. This type of study may be used in the identification and quantification of species for conservation purposes. (Supported by NIH-NIGMS MBRS Grant, GM 45455-07 and NIH-FIC MIRT Grant TW 00033-05, Barry University)

11:00 AM BIO-10 Investigation into the seed bank of a Florida scrub community, Southwest Hernando County, Florida. CHERYL L. BERRY, Dept. of Environmental Science, Saint Leo College, St. Leo, FL, 33574. Florida has unique scrub habitats which may contain many species of plants which are endemic to Florida. This study investigates the seed bank densities and seasonal fluctuations for herbaceous and woody species in this droughty, infertile, upland community. The abundance of seeds in the soil samples obtained from scrub sites was quantitatively analyzed by visual inspection of the soil and by soil treatments for seedling emergence. Variation in seasonal seed densities, and in the viability of seeds were observed. Also, the differences between the seed densities for woody and herbaceous species were evident. The seed bank has an essential role in maintaining the scrub habitat.

11:15 AM BIO- 11 Evaluating the status of wetlands using a rapid, qualitative procedure. PATRICIA DOORIS (1) AND GEORGE DOORIS (2), (1) Dept. of Environmental Science, Saint Leo College, Saint Leo, FL 33574 and Institute for Environmental Studies, Univ. of South Florida, Tampa, FL 33620, (2) Dept. of Mathematics and Science, Saint Leo College, Saint Leo, FL 33574. Because hydroperiod is the single most important factor in wetland maintenance, its abbreviation by either natural or man-made causes brings about detectable changes in wetlands so affected. A convenient method for evaluating the results of shortened hydroperiod has been developed and tested on wetlands in central Florida. The method employs the recording on a standard field sheet of systematic observations on five wetland biological and physical characteristics, and it results in a numerical index of habitat quality. Indices were calculated for 35 wetlands for the period 1988-97 using data collected during August of each year. The indices compared well with other data on the wetlands. The value of the method resides in its reproducibility, its ease of use, and its correlation with other status indicators. Also, it can be applied to previous conditions, allowing wetlands to be described by the same relative index over a long period of time despite different modes of data collection in the past.

11:30 AM BIO-12 Comparative study on avian utilization of two adjacent water bodies: Storm Water Retention Pond and Tampa Bay. J.A. MICHAEL, P.M. DOORIS, Saint Leo College, Saint Leo, FL 33574. Comparative data were gathered on avian utilization of freshwater and saltwater habitats in central Florida from April 1997 to March 1998. Species observed were divided into five foraging guilds. Despite its small size (<1 acre) and urban location, the freshwater site experienced approximately seven times more utilization than the saltwater site. The highest density of birds was observed in the month of January 1998. Most of the species observed were year-long residents of Florida; although three species of winter residents were also recorded. Federal/State listed species utilized these two sites. The data suggests the value of the small, artificial water bodies in promoting avian populations.

11:45 AM BIO-13 Sediment composition of two tropical coastal freshwater ponds, Macaé, RJ, Brazil. C. STALLMAN (1), T.L. CRISMAN, (1), F.E. ESTEVES (2), (1) Center for Wetlands, University of Florida, PO Box 116350,Gainesville, FL 32611, (2) Lab. de Limnologia, Dept. of Ecologia, Universidade do Rio de Janeiro, Rio de Janeiro, RJ, Brazil. Coastal lagoons span approximately 1,500 miles of the Atlantic coast of Brazil. Similar systems are located along the coast of Florida's panhandle. Both of these areas are rapidly being encroached by human development. The Brazilian lagoons are used as sources of freshwater and recreation by the local population and are impacted through discharge of sewage effluent and agricultural runoff. The main objective of this study is to characterize sediments of two tropical freshwater ponds located in the city of Macaé, RJ with contrasting anthropogenic impacts. Ten sediment-water interface cores were collected from the ponds and analyzed for organic matter content. Select cores were dated using the ^{210}Pb radiometric technique. The role sediments play in recording environmental change in a tropical environment is discussed.

12:30 PM LUNCH

2:30 PM BIO-14 The role of a wild bird rehabilitation center in preserving seabirds. AMY L. LONG, SNHS-Biology, Barry University, 11300 NE 2nd Avenue, Miami Shores, FL 33161. Wild Bird Rehabilitation Centers play a role in the preservation of seabirds. From the point of view of an intern at the Florida Keys Wild Bird Rehabilitation Center, in Tavernier, FL, I will describe the work carried out by the Center and its staff. This includes the types of birds handled (both endangered and non-endangered), the nature of their injuries and the effectiveness of procedures used to rehabilitate the birds. The educational role of the Center will also be discussed. Thus the Center provides a service not only to the birds it helps, but also to the general community and its visitors. Supported in part by NIH-MARC grant and Barry University.

2:45 PM BIO-15 Presence of a Blue Morph of the Freshwater Crayfish *Procambarus fallax* (Hagen) in Palm Beach County, Florida. PEGGY G. VANARMAN . Palm Beach Atlantic College. PO Box 24708 West Palm Beach , Florida. 33416-4708. During distribution studies of freshwater crayfish throughout Palm Beach County, male and female blue morphs of *Procambarus fallax* were captured from a drainage canal. Blue crayfish represented a minute proportion of a normally brown colored crayfish population. Theories on causes of blue colors in crayfish include genetic variations, food, sunlight, environmental pollution and colors prevalent during mating seasons. Evidence indicates that the blue color is genetically based. Crayfish are an important component of the freshwater food chain in South Florida. Recent studies related to restoration of the Everglades indicate that crayfish, as a key indicator species, provide food for important species of fish, reptiles and wading birds. Visuals of blue crayfish mating and eating will be presented.

3:00 PM BIO-16 Connecting biology to community through service-learning. J. OSTROFF, Brevard Community College, 1519 Clearlake Road, Cocoa, FL 32922. Historically, Biology has tended to remain publicly viewed as an iconoclastic discipline with little direct link into everyday life and society with the exception of the new DNA work in legal arenas. Students in Biology courses generally see the course as a compendium of facts and meaningless laboratory experiments. They view Biology as a course they must take as a requirement of graduation and see no link between the discipline and their lives and futures. By implementing service-learning into Biology courses Students can be shown how Biology content, Principles, and methodology impacts everyday life. This presentation will discuss the historic role of service learning as a means of connecting students in Biology courses to their roles in society and how service learning expands the course beyond the limitations of the classroom/laboratory environment in a meaningful and impactful manner that cannot be achieved by simple lecture and laboratory methodology. A review of currently offered programs will be presented to show how to implement service learning in a variety of meaningful circumstances without having to disrupt or rewrite the structure of the course. Time will be spent assisting audience faculty in beginning to develop service-learning components for their respective courses.

3:15 PM BUSINESS MEETING: BIOLOGICAL SCIENCES
JEREMY MONTAGUE, presiding

COMPUTER & MATHEMATICAL SCIENCES

FRIDAY, 3:30 PM PHYSICS 108
FRED BUONI, FLORIDA INSTITUTE OF TECHNOLOGY, presiding

3:30 PM CMS-1 Dynamics of Diffusive-Reaction Cells for Solid-Gas Systems: An Operator Theoretic Approach. K. GAWRYCS (1), P. ARCE (1, 2), AND J. TELOTTE (1). (1) Department of Chemical Engineering, FAMU-FSU College of Engineering, (2) Geophysical Fluid Dynamics Institute, GFDI, Florida State University, 2525 Pottsdamer Street, Tallahasse, FL 32310-USA. The dynamics of gas-solid cells is important in many laboratory applications to understand the physics of the adsorption-desorption processes in many relevant cases to chemical engineering applications. These could include, for example, chromatographic separations, adsorption of gaseous contaminants on solid surfaces, and heterogeneous chemical reactions, among other cases. In this contribution, an operator-theoretic analysis is conducted to characterize the dynamic behavior of a well-mixed continuous cell. The approach leads to self-adjoint operators whose spectra are effectively used to study a variety of possible dynamic behaviors. Applications to parameter determination are addressed.

3:45 PM CMS-2 Improving the quality of Engineering Education using Juran's Triprol and Trilogy methodologies. G. GARRIDO, F. B. BUONI, J. HADJILOGIOU, Florida Institute of Technology, 150 West University Blvd., Melbourne, FL 32901. We investigate the application of Juran's Triprol and Trilogy methodology to model and improve the educational process at a technical university. We constructed the quality system matrix within the context of the university, college, course, academic program, and course levels. For each level, we then identified the quality categories, stakeholders, needs, product design, and process designs. Finally, we applied the methodology to a course to demonstrate how to apply the methodology.

4:00 PM CMS-3 Implementing a Parallel Option Assessment Process under Time Constraint. OMSRI BANDITVILAI and F. B. BUONI, Florida Institute of Technology, 150 West University Blvd., Melbourne, FL 32901. We apply a method for parallel processing of the skill-based, rule-based and the knowledge-based decision modes in Buoni's general decision architecture. This method is applied to simulation the a nuclear test reactor using expert systems to implement the decision modes. The used of an urgency vector ensures that the best decision is taken at the time that a decision is required.

4:15 PM BUSINESS MEETING: COMPUTER & MATHEMATICAL SCIENCES
FRED BUONI, presiding

ENGINEERING SCIENCES

FRIDAY, 2:30 PM PHYSICS 108
FRED BUONI, FLORIDA INSTITUTE OF TECHNOLOGY, presiding

2:30 PM ENG-1 Particle Characterization in Sewage Water Electrosettling. G. MILLER (1), P. PALMER (1), W. FINNEY (1), P. ARCE (1, 2) (1) Department of Chemical Engineering, FAMU-FSU College of Engineering, (2) Geophysical Fluid Dynamics Institute, GFDI, Florida State University, 2525 Pottsdamer Street, Tallahassee, FL 32310-USA. Successful preliminary experiments have been conducted in the sedimentation of sludge particles from sewage water using external electrical fields. The particles contained in waste water samples show a remarkable variety of shapes and sizes that affect the rate of sedimentation in the electrosettling chamber. Therefore, careful particle characterization must be performed in order to understand the effect of the electrical field. This contribution will discuss a microscopic approach to characterize the size, shape, and concentration distribution of the particles present in sewage water samples

2:45 PM ENG-2 Electro-assisted Sedimentation of Sludge Particles in Sewage Water Samples. P. PALMER (1), G. MILLER (1) W. C. FINNEY (1), P. ARCE (1, 2) (1) Department of Chemical Engineering, FAMU-FSU College of Engineering, (2) Geophysical Fluid Dynamics Institute, GFDI, Florida State University, 2525 Pottsdamer Street, Tallahassee, FL 32310-USA. The sedimentation of sludge particles is the slowest operation in the successful clarification and recycling of sewage water. The application of an external applied electrical field has been proven to increase the rate of sedimentation of the particles in a small-scale electrosettler. In this contribution, details about the different strategies in the application of the electrical field and the effect of the inclination of the electrosettling chamber will be discussed. Illustrative results will be presented and recommendations for future work will be given.

3:00 PM ENG-3 Preliminary Model to Understand Particle Sedimentation in Electrosettling Devices. M. SMITH (1), P. ARCE (1, 2) and W. C. FINNEY (1). (1) Department of Chemical Engineering, FAMU-FSU College of Engineering, (2) Geophysical Fluid Dynamics Institute, 2525 Pottsdamer Street, Tallahassee, FL 32310-USA. The motion of particles in electrosettling devices is poorly understood. In addition to gravitational forces, the particle is exposed to electrically driven forces that may or may not help to accelerate the speed of sedimentation. In this contribution, a preliminary model is introduced to describe the motion of particles sedimenting under an applied electrical field. The model is helpful to calculate the trajectories of the particles. Details, limitations, and some numerical illustrations will presented.

3:15 PM BUSINESS MEETING: ENGINEERING SCIENCES
FRED BUONI, presiding

ENVIRONMENTAL AND CHEMICAL SCIENCES

FRIDAY, 8:15 AM PHYSICS 118
SESSION A
DEAN MARTIN, UNIVERSITY OF SOUTH FLORIDA, presiding

8:15 AM ENV-1 The history of organic geochemistry: Globally and at Florida Atlantic University. J. W. LOUDA and E. W. BAKER. Organic Geochemistry Group, Florida Atlantic University, 777 Glades Road, Boca Raton, FL. 33431. In the years 1934 - 1936 Professor Alfred Treibs of Germany reported on the structural similarity of geochemical and biological pigments. Specifically, he related deoxophylloerythroetioporphyrin (DPEP) and several etioporphyrins (ETIO) which he isolated from oil shales to chlorophyll-*a* and hemes, respectively. These findings allowed the proposition that petroleum most likely had biologic beginnings. This concept was independently confirmed by others using optical activity measurements. Organic geochemistry (OG) encompasses the study of all classes of biogeochemicals and traces their source, reactions and fates in sediments, shales, peats, coals, and petroleum. OG, intensely studied within the oil industry, has led to a great many analytical advances (*e.g.* GC-MS) and offers insight to the overall carbon-cycle. Organic geochemistry at FAU has included studies on hydrocarbons, steroids, carotenoids, and chlorophylls plus their derivatives in deep-sea sediments recovered by the Deep-Sea Drilling Project, *in vitro* experimentation with pure compounds or phytoplankton and bacteria, lacustrine waters and sediments, marine waters and shelf sediments, and a wide variety of oil shales, peats, coals, and petroleum crudes.

8:30 AM ENV-2 Carotenoid geochemistry. J. W. LOUDA. Organic Geochemistry Group, Florida Atlantic University, 777 Glades Road, Boca Raton, FL. 33431. In a landmark paper on carotenoid geochemistry (Carotenoid pigments in the ocean floor, *Arch.Biochem.* v.5, pp. 1- 23), Professor Denis Fox and co-workers noted the predominance of the hydrocarbon carotenoids, the carotenes, over oxygenated forms, then called the 'xanthophylls'. Additionally, they made note that the reverse is true in source biota and that either a preferential degradation and / or an interconversion occurs in sediments. For years, the bulk analyses of carotenoids in sediments included determination of the "H/E" value as a measure of the carotenes-to-xanthophylls in the hypophase or epiphase, respectively, of a partition between petroleum ether and aqueous 90% methanol. Little knowledge was added to this field for approximately 3 decades following the report of Fox *et al*., 1944. The present report covers the rapid progress made in the field of carotenoid geochemistry within the last 2 decades and includes many examples from both our studies and those reported in the literature. Initial diagenesis can be viewed as funneling many carotenoids (*e.g.* fucoxanthin, diadinoxanthin) into the general pool of carotenols. Upon increased depth of burial, carotenols can be observed to give rise to geochemical carotenes. Thus, at considerable age/depth only carotenes and aryl-carotenoids survive, as found by Fox and others since.

8:45 AM ENV-3 Phytoplankton senescence and death-related degradation of chlorophylls and carotenoids. L. LIU, J. W. LOUDA, and E. W. BAKER. Organic Geochemistry Group, Florida Atlantic University, 777 Glades Road, Boca Raton, Florida 33431. In order to assess the biogeochemical degradation of chlorophylls and carotenoids, log-phase cultures of five phytoplankton species were placed in the dark under oxic (open / periodically mixed) or anoxic (N_2 sparged) conditions at either warm / room (24°C) or cold / refrigerator (4°C) temperatures. Experimental design was meant to mimic the onset of senescence and eventually death which results when cells fall out of the euphotic zone. The species investigated were: Anacystis nidulans (cyanobacterium), Coccolithophora (coccolihtophore), Gymnodinium sp. (dinoflagellate), Thalassiosira sp. and Cyclotella maneghiniana (diatoms). Chlorophyll-*a* [CHL*a*] degradation was found to be accelerated or retarded in warm-oxic or cold-anoxic conditions, respectively, and exhibited species-specificity as to alteration with or without concurrent phytyl hydrolysis. The degradation of diadinoxanthin, to diadinochrome or to diatoxanthin and subsequently to a *cis* isomer of zeaxanthin was observed in all species except A. nidulans, as it obviously lacks this compound. Senescent / death-related pigment alterations will be discussed as precursors to true organic diagenesis.

9:00 AM ENV-4 Diagenesis of chlorophyll-*a* and bacteriochlorophyll-*a* in Florida Bay sediments. J. W. LOITZ (1), J. W. LOUDA (1), D. T. RUDNICK (2), and E. W. BAKER (1), (1) Organic Geochemistry Group, Florida Atlantic University, 777 Glades Road, Boca Raton, FL. 33431, (2) Everglades Research Division, South Florida Water Management District, 3301 Gun Club Road, West Palm Beach, FL. 33416. This report covers the analyses of biopigments in 4 cores (0.6 - 1.2 m) taken in north-central Florida Bay. Surficial sediments contained pigments (*e.g.* chlorophylls-*a*, -c_1/-c_2., 'bacterio-*a*', fucoxanthin, zeaxanthin, spirilloxanthin) in distributional sequences and amounts which indicate a microphytobenthos comprised of a diatomaceous cyanobacterial biofilm-to-mat underlain with purple-S bacteria. Bacteriochlorophyll-*a* was found to degrade to bacteriopheophytin-*a* and its epimer (-*a*') with depth. Chlorophyll-*a*[CHL*a*] was observed to be rapidly converted, with or without the intervention of chlorophyllide-*a*, to pheophorbide-*a* and subsequently to pyropheophorbide-*a*. These changes occurred rapidly in the uppermost 10 cm. Proceeding downhole, the conversion of pyropheophorbide-*a* to cyclopheophorbide-*a* *via* a base-catalyzed Dieckmann cyclization was found and CYCLO then formed the overwhelmingly major CHL*a* derivative. These early diagenetic reactions are discussed in the context of overall tetrapyrrole geochemistry.

9:15 AM ENV-5 Analysis of Bretoxin on Biological System. M.L. DERBY[1], J.J. KRZANOSKI[2], D.F. MARTIN[1]. [1]Institute for Environmental Studies. University of South Florida Tampa, FL 33613. [2]Department of Pharmacology and Therapeutics. College of Medicine. University of South Florida Tampa, FL 33613. Brevetoxin, originating from the Florida red tide Gymnodinium breve, was isolated and stored in a freezer for a period ranging from weeks to twelve years. Preliminary results indicate that Brevetoxin that has been stored at 0 degrees Celsius for a twelve-year period still has some strong activity. The results show that the toxin will cause contraction of the airways smooth muscle and the aortic smooth muscle. Also testes was recently isolated brevetoxin, which was more potent and achieved the same preliminary results.

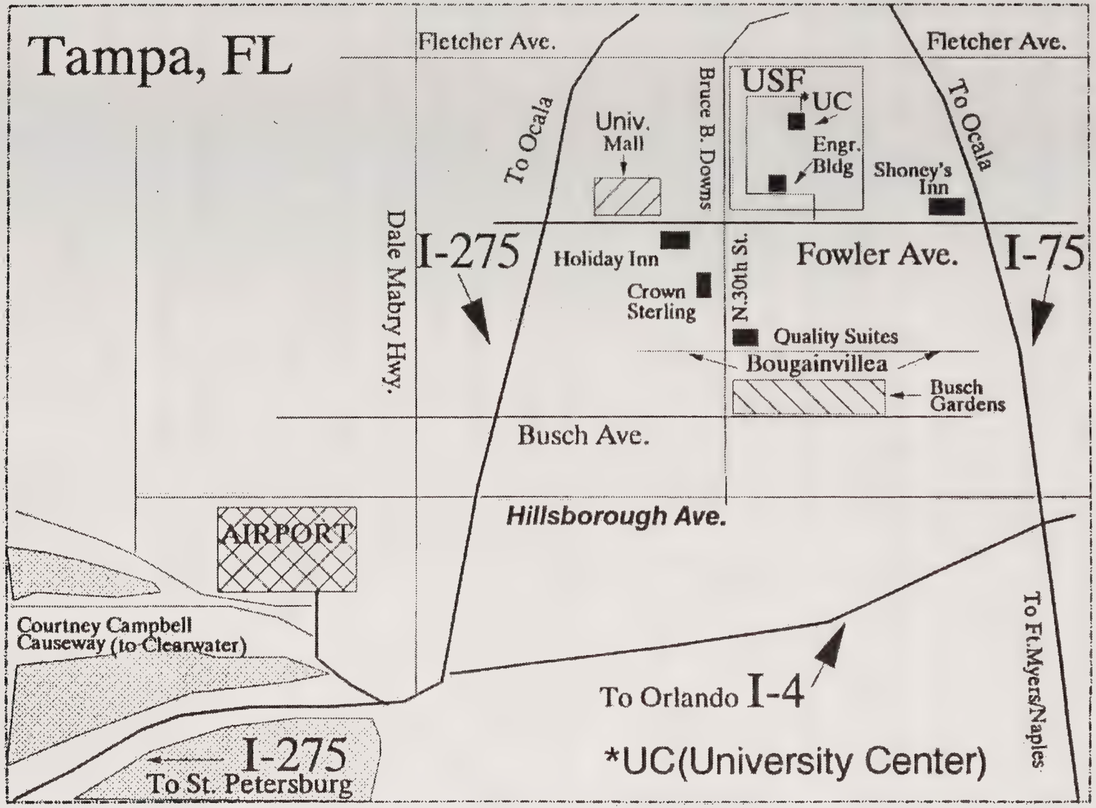
9:30 AM BREAK

10:00 AM ENV-6 Selenium Supplementation of Selected Floridian Agricultural Crops. K. EASTMAN, R. F. BENSON, M. T. GALLARDO, AND D. F. MARTIN. Institute for Environmental Studies, Department of Chemistry, University of South Florida, 4202 East Fowler Avenue, Tampa, Florida 33620. Selenium has been found to have anticarcinogenic properties and therefore is considered to be an essential element to have in our daily diet. However, a majority of the foods we intake do not contain appreciable amounts of selenium. Selected crops grown in the Tampa Bay area were supplemented with selenium and analyzed in order to determine the feasibility of artificial selenium supplementation.

10:15 AM ENV-7 Bioremediation of Selenium by Selected Wetland Species. K. EASTMAN, R. F. BENSON, M. T. GALLARDO, AND D. F. MARTIN. Institute for Environmental Studies, Department of Chemistry, University of South Florida, 4202 East Fowler Avenue, Tampa, Florida 33620. Selenium is found in trace amounts in most areas of the United States. However, in some areas the amount of selenium that exists naturally in the soil is so abundant, that it is responsible for the toxic deaths of livestock. Bioremediation has been studied in order to alleviate this problem, as well as selenium contamination. Selected wetland species were exposed to high amounts of selenium and the amount absorbed by the wetlands species was analyzed.

10:30 AM ENV-8 Inhibition of Florida's Red Tide Organism by Nannochloris eucaryotum. E. PÉREZ AND D. F. MARTIN. Institute for Environmental Studies, Department of Chemistry, University of South Florida, 4202 E. Fowler Ave., Tampa, FL 33620. The green alga Nannochloris eucaryotum is allelopathic toward Florida's red tide organism, Gymnodinium breve. Several biophysiochemical factors of N. eucaryotum were studied. These include acclimation to salinity similar to the one present in the Gulf of Mexico, first-order growth rate, and doubling time. In addition, allelochemicals were isolated and attempts were made to characterize them.

10:45 AM ENV-9 Determination of the Critical Micelle Concentration of the Allelochemicals Produced by Nannochloris oculata and their Effect on Rabbit Erythrocytes. E. PÉREZ, M. DERBY, P. GRIVAS AND D. F. MARTIN. Institute for Environmental Studies, Department of Chemistry, University of South Florida, 4202 E. Fowler Ave., Tampa, FL 33620. Nannochloris oculata is allelopathic toward Florida's red tide dinoflagellate, Gymnodinium breve. The allelochemicals were identified and found to be two surfactants. The critical micelle concentration was determined, along with the effective concentrations on G.


Tampa, FL
Fletcher Ave.
Fletcher Ave.
To Ocala
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Univ.
Mall
Bruce B. Downs
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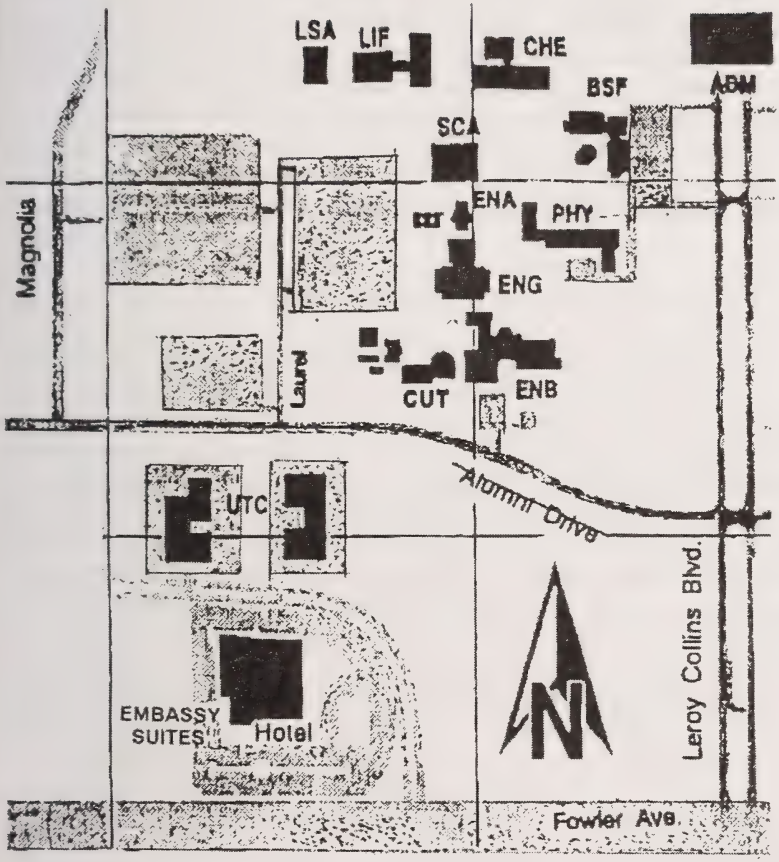
Shoney's
Inn
Dale Mabry Hwy.
I-275
Holiday Inn
Crown
Sterling
N.30th St.
Fowler Ave.
I-75
Quality Suites
Bougainvillea
Busch
Gardens
Busch Ave.
Hillsborough Ave.
AIRPORT
Courtney Campbell
Causeway (to Clearwater)
To Orlando I-4
I-275
To St. Petersburg
*UC(University Center)
To Ft.Myers/Naples



ADM	Administration	ENB	Engineering Bldg. II
BSF	Biosience Facility	ENG	Engineering
CHE	Chemistry	LIF	Life Science
ENA	Engineering Auditorium	PHY	Physics

Registration will be in the Physics Building

breve. The effect of these two surfactants on rabbit erythrocytes was evaluated.

11:00 AM ENV-10 Setting the Record Straight. Are Cattails Phytotoxic or Not? M. T. GALLARDO AND DEAN F. MARTIN. Institute for Environmental Studies, Department of Chemistry, University of South Florida, Tampa, FL 33620. Some literature reports indicate that cattail species contain and are able to release phytotoxins that are autotoxic and also prevent the growth of other species. Other references fail to find evidence to support these observations. The contradiction seems to arise because the phytotoxicity of the cattail material is dependent on several factors. We will explore some of those factors (which include concentration, decomposition time, decomposition pathway, and seasonality) in order to reconcile the available evidence.

11:15 AM ENV-11 Phyto-Accumulation Of Heavy Metals By Aquatic Plants. M. T. GALLARDO, R. F. BENSON, AND D. F. MARTIN, Institute for Environmental Studies, Department of Chemistry, University of South Florida, Tampa, FL. 33620. A Lead-acid battery manufacturing plant was located at the northwest junction where Delaney Creek crosses U. S. Highway 41 in south Tampa. The creek bed and banks in the vicinity of this were contaminated with lead residues. Previous studies have shown that lead was present in the creek water and creek bed near this battery plant site. Representative plants growing along the creek are being collected and analyzed for lead accumulation.

11:30 AM BUSINESS MEETING: ENVIRONMENTAL AND CHEMICAL SCIENCES
DEAN MARTIN, UNIVERSITY OF SOUTH FLORIDA, presiding

FRIDAY 2:30 PM
SESSION B
CHERIE GEIGER, UNIVERSITY OF CENTRAL FLORIDA, presiding

2:30 PM ENV-12 Examining the Sorptive Characteristics of Different Zero-Valent Iron Surfaces. C.L. GEIGER (1), C.A. CLAUSEN (1), D.R. REINHART (2), P. TOY (1), N. RUIZ (3). N. CHAN (1). J. QUINN (4). Departments of Chemistry (1) and Civil and Environmental Engineering (2), University of Central Florida, Orlando 32816, GeoSyntec, Huntington Beach, California (3), NASA, Kennedy Space Center, Florida (4). The use of zero-valent iron has gained popularity for use in groundwater remediation of chlorinated organic solvents. It was found in laboratory experiments that the concentration of trichloroethylene (TCE) decreased dramatically during the first 24 hours of exposure to iron. Work described in this study has incorporated the use of ultrasonic energy to remove sorbed species from the iron surface and subsequently measure the aqueous concentration of organics. This research showed that the initial physical phenomenon that takes place in this reaction is sorption of the chlorinated organic to the iron surface. After application of as little as 45 seconds of ultrasonic energy, organic compounds were released from the iron surface. An aqueous solution of TCE was exposed to iron powder and samples were taken both before and after exposure to ultrasound. It was found that sorption accounted for 5-10% of the TCE mass during the first 24 hrs. of the experiment which explains the nonlinearity of kinetic date. It was also found that the by-products of the reaction have similar sorptive characteristics.

2:45 PM ENV-13 Comparing the Importance of Variables Involved in the Electrokinetic Remediation of Soils Contaminated with Heavy Metals. VANESSA N. PRASAD (1), C. L. GEIGER (1), C. A. CLAUSEN (1), D. REINHART (2), CINDI NANDALL (1) University of Central Florida, Department of Chemistry(1) and Civil and Environmental Engineering(2), Orlando, 32816-2366. Metals such as zinc and lead are common soil contaminants at industrial sites and current remediation technologies are not useful in areas where surface or subsurface structures exist. Electrokinetic remediation is useful in these instances because it requires little disruption of the remediation site and is cost efficient. The process involves using d.c. current passed through an electrode pair installed in the soil to a depth of approximately three feet. Conditioning fluids are passed through the treatment area to help control pH and to increase the conductivity of the soil matrix. Results will be presented comparing various variables involved in the process.

3:00 PM ENV-14 A Study to Determine the Effectiveness of Ultrasound for Field Application with a Permeable Treatment Wall. KRISTI FARRELL(1), C. L. GEIGER(2), C. A. CLAUSEN(2), D. R. REINHART(1), J. QUINN(3), Departments of Civil and Environmental Engineering(1) and Chemistry(2), University of Central Florida, Orlando, Florida, 32816, NASA, Kennedy Space Center, Florida(3). Funded by NASA, Kennedy Space Center. Groundwater contamination by chlorinated solvents has been found at many sites throughout the United States. The development of cost-effective methods for remediating contaminated groundwater is an important issue in environmental research. Permeable treatment walls that use zero-valent iron as a reducing agent are a recently developed technique for use in this kind of remediation effort. However, plugging and fouling of these structures is a concern with regards to long term treatment. Ultrasound has been evaluated in laboratory studies as a method for rejuvenating the reactivity of the iron in situ. This work involves sampling and analysis at a field site before and after application of ultrasound. Additionally, iron from the field site was recovered and its reactivity examined in laboratory experiments.

3:15 PM ENV-15 The Control of Nitrogen Oxide Emissions from Stationary Power Sources by Hydrogen Peroxide Injection into Flue Gas. C.A. CLAUSEN (1), L. TAZI (1), C.D. COOPER (2), Q NGUYEN (2), AND M. COLLINS (3). University of Central Florida, Departments of Chemistry (1) and Civil and Environmental Engineering (2), Orlando FL 32816, NASA, Kennedy Space Center (3). This paper focuses on a project that had the objective of developing an inexpensive control method that is capable of reducing NO_x and SO_x emissions and one that could be used by a wide variety of stationary power generating plants. The methodology is based on the property of hydrogen peroxide that when it is vaporized it can be caused to split into OH radicals. The very reactive OH radicals then oxidize NO and NO_2 into the more soluble HNO_2 and HNO_3 species. This process was studied in the laboratory and was scaled up to pilot plant size. A number of operational problems were encountered and their solutions are discussed. Data and conclusions will be presented along with future plans for possible commercialization of the process.

3:30 PM BREAK

4:00 PM ENV-16 Isolation of the Effects of an Applied Magnetic Field upon Carbonate Scale Formation. R.F. BENSON AND D.F. MARTIN, Institute for Environmental Studies, Department of Chemistry, University of South Florida, Tampa 33620. Magnetic fields have been used to treat hard water scale deposits on pipes and boilers for many years. The treatment usually involves passing a saturated fluid or solution through a magnetic field to effect a delay of the onset of crystallization until the fluid or solution has moved to a more acceptable location. However, deposited solids are also affected by the magnetic field. This work explores the relative contributions of the shift of particle size distribution to smaller size and the apparent shift of equilibrium that gives rise to scale removal.

4:15 PM ENV-17 Full Elemental Complement Foods. J.W. PALMER. Institute for Environmental Studies, Dept. of Chemistry, University of South Florida, Tampa, FL 33620-5250. Many soils in the world that are farmed are so deficient in trace elements that they give very poor crop yields. Those crops that are harvested are in turn very low not only in trace elements, but also in minor and major elements. Thus they do not provide the necessary nutrients to give healthy human populations. Suggestions are made on ways to improve crop production of quality products.

4:30 PM ENV-18 Nitrate, Nitrite and Nitrosamine Analyses of Foods, Tobacco, and Physiological Fluids. R.S. BRAMAN. Institute for Environmental Studies, Department of Chemistry, University of South Florida, Tampa, FL 33620. The use of a chemiluminesence type detector continues to be applied to a variety of analytes. Detection limits are in the nanogram range. Specific detection is obtained by the use of selective reduction solutions. Results of analyses will be presented.

SATURDAY 9:00 AM
SESSION C
BARBARA MARTIN, presiding

9:00 AM ENV-19 The Gradual Acceptance of the Periodic Chart. J. S. ROBINSON, Department of Physical Science, Seminole Community College, Sanford 32773. Although Mendeleeff presented his Periodic Chart in a paper to the German Chemical Society in 1869, acceptance of what chemists now consider their most important tool was a gradual process. Mendeleeff himself in his 1891 text includes the Periodic Law in the appendix. Ira Remsen, often called the father of American chemical education, covered the "periodic system" in Chapter 11 of his 1889 text, with no major changes in his 5th edition of 1902. Edgar Fahs Smith at the University of Pennsylvania in all editions of his text from 1908 through 1920 relegates the periodic system to the final chapter. William Noyes at the University of Illinois in 1919 and Harry Holmes at Oberlin in 1930 cover the periodic law in Chapters 19 and 20, respectively. By 1937 B. Smith Hopkins at Illinois treated it in Chapter 3, essentially where we find it today, but it was not until the 1950's that it became routine for the Periodic Chart to appear inside the front cover of every chemistry text. This project was supported by a sabbatical semester from Seminole Community College and by access to the Edgar Fahs Smith rare book collection at the University of Pennsylvania.

9:15 AM ENV-20 Active Learning in Environmental Chemistry. JEROME E. HAKY AND NANCY ROMANCE. Florida Atlantic University, Boca Raton 33431. Environmental Chemistry is a subject in which non-traditional methods of teaching and learning can easily be employed. We recently introduced such methods in two graduate environmental analytical chemistry courses, one designed for students in a traditional M.S. program in Chemistry, and one targeted towards students in a new multidisciplinary M.S. program in Environmental Science. Group activities, role-playing and critical thinking exercises were continuously employed in both courses to stimulate creative solutions to practical environmental problems. Understanding of modern methods of chemical analysis was reinforced through cognitive-based learning techniques, such as concept mapping. Examples of these new techniques will be discussed. Additionally, the attitudes of students in the two courses towards these new methods and their relative success in mastering the course material will be compared.

9:30 AM ENV-21 Challenges of a Chemical History Course, DEAN F. MARTIN, Institute for Environmental Studies, Department of Chemistry, 4202 E. Fowler Ave., Tampa, Fl 33620-5250. "Historical Perspectives of Chemistry, " a course for juniors and seniors at USF, is a Gordon-Rule class that may also satisfy a USF exit requirement. Teaching such a course represents several challenges including the topics to cover, required emphasis on diversity, technical level, a balance between instructor and student expectations, and what written material to cover. The course also includes some demonstrations and a breakdown of the writing requirement, designed to provide manageable amounts of material that permit rapid feed-back and prevent the opportunity for cheating. Feedback provided to the instructor suggests a fair degree of success with appropriate room for improvement.

9:45 AM ENV-22 Computer-Interfaced Chemistry Laboratory Instruction. R. F. BENSON and M. T. GALLARDO, Department of Chemistry, University of South Florida, Tampa, FL 33620. Recent acquisitions of instrumentation to the teaching laboratory has been accompanied by computer or microprocessor control of the data acquisition. However, the use of the computer interfaced to a laboratory experiment rather than a specific instrument has changed the mechanism of the teaching laboratory experience. Initially the students were able to collect and manage more data in less time, but further extension of the computer utilization led to better quality of laboratory reports and eventually to student design of experiments to solve problems.

10:00 AM BREAK

10:30 AM ENV-23 Teaching Strategies for Chemistry Teaching Assistants. M.T. GALLARDO. Institute for Environmental Studies, University of South Florida, Tampa, FL 33620. Most of the undergraduate chemistry laboratory instruction is being supervised by graduate teaching assistants who may or may not be well prepared for the challenges of such a course. As part of a short introductory teaching training, teaching assistants at USF are presented with a number of strategies to introduce active learning in the laboratory. This strategies, as well as preliminary data on the success of the program will be presented.

10:45 AM ENV-24 Novel Glycosidases Inhibitors: Synthesis of β-halo thiosugars. S. XU, E. TUROS*. Dept. of Chemistry, Univ. of South Florida, 4202 E. Fowler Avenue, CHE 305, Tampa, FL 33620-5250. Over the last several years, efforts to design and synthesize inhibitors of glycosidases have been made because these compounds promise to be valuable tools for probing the details of catalytic mechanisms, and also for a potential therapeutic agent for cancer and AIDS. Our research is exploring a novel class of potential glycosidases inhibitors known as thiosugars which are carbohydrates having a sulfur atom is place of the ring oxygen. This talk will describe the synthesis of new thiosugars using previously unexplored synthetic routes.

11:00 AM ENV-25 Antibiotics in the Twentieth Century. J. R. ASCHER, E. T. CARPENTER AND E. TUROS, Department of Chemistry, University of South Florida, 4202 E. Fowler Ave., Tampa 33620. Antibiotics, arguably one of the greatest advances in medical science, were developed in this century. We will give a brief historical overview of anti-microbial agents used prior to the discovery of penicillin such as: mercuric compounds, arsenic compounds and sulfa drugs. Then we will discuss the discovery of penicillin and its mode of action. We will then compare penicillin to these earlier therapeutic regimes. After the discovery of penicillin many derivatives were rapidly developed. We will outline these, the main antibiotic families. Over the past decade, many of the previously effective antibiotics have failed due to resistant bacteria. The new research focuses on antibiotics which are different enough to combat the resistant strains of bacteria. We are currently engaged in one branch of this new research, mono-cyclic beta lactams. A summary will be given of this new research.

11:15 AM ENV-26 Advances and Current Research in Antibiotics. E. T. CARPENTER AND E. TUROS, Department of Chemistry, University of South Florida, 4202 E. Fowler Ave., Tampa 33620. The development this century of antibiotics has given us one of the most effective tools medical science has to combat disease. Before the use of antibiotic infectious diseases were the leading cause of death among all age and social/economic groups. Once endemic disease are now almost unheard of as a major health concern. This condition though may be under threat because of the emergence in recent years of resistant strains of bacteria. Previously effective antibiotics are failing due to these virulent bacteria. In this paper we will focus on the new research being conducted by ourselves, and others, into novel antibiotics and therapeutic regimes. Some of these new antibiotic, in contrast to the present ones, are accessed though purely synthetic chemical pathways.

11:30 AM ENV-27 Spinning Methyls: Computational Predictions of Molecular Conformation in a New Class of Beta-Lactam Antibiotics. E.F.WILSON and E.TUROS. Department of Chemistry, University of South Florida, 2402 East Fowler Avenue, Tampa, FL 33620-5150. As drug-resistant strains of bacteria become more common, development of new anti-bacterial agents gains ever-increasing importance. In the effort to explore potential new anti-bacterials, we are investigating novel beta-lactams that are similar in structure to the monobactam family of drugs, but which have an unusual N-SCH_3 bond linkage. In the pursuit of understanding the reactivity and antibacterial properties of this class of molecules, several specific beta-lactams are being modeled by computer. In these studies, the energetics for the rotation about the N-SCH_3 bond are examined.

11:45 AM ENV- 28 Research on Monocyclic Beta-Lactam Antibiotics. T. E. LONG and E. TUROS, Department of Chemistry, University of South Florida, 4202 E. Fowler Ave., Tampa, FL 33620. Monocyclic beta-lactams are effective in their use as antibacterial compounds. The physiology of bacterial reproduction and the proficiency of beta-lactams to inhibit reproduction will be described. Our current research focuses on the synthesis of a new class of monocyclic structures similar to the beta-lactam. The reactions used to synthesize the compound and the mechanisms involved will be discussed. Biological testing of the monocyclic compound and its significance to beta-lactam antibiotic research will then be examined.

FAS POSTER SESSION (ENV)
SATURDAY, 9:30 AM – 11:30 AM
PHYSICS HALLWAY

POS-1 Effect of Cattail (*Typha domingensis*) Extracts on Selected Submerged Species. M. T. GALLARDO, R. L. BARTON, M. D. SCHODERBOCK, B. B. MARTIN, AND D. F. MARTIN. Institute for Environmental Studies, Department of Chemistry, University of South Florida, Tampa, FL 33620.

POS-2 Modeling Organism-Organism Interactions as a Means of Predicting Florida Red Tide Management Potential. F. A. BOOTH, E. PÉREZ AND D. F. MARTIN. The interaction of Nannochloris. oculata, which produces cytolytic substances toward Florida's red tide organism, Gymnodinium breve, is considered through computer modeling. The interaction was reviewed through the use of differential equations and a computer program called TK Solver 3.32.

POS-3 Analysis of Selenium Supplement Tablets. K. EASTMAN, R. F. BENSON, F. A. BOOTH, M. J. COLLIER AND D. F. MARTIN. Institute for Environmental Studies, Department of Chemistry, University of South Florida, 4202 East Flowler Avenue, Tampa, Floria 33620

POS-4 Central Florida Trends in Rainwater Chemistry from 1978 to the Present. B.C. MADSEN(1), T.W. DRESCHEL(2), AND L.A. MAULL(2).(1) University of Central Florida, Department of Chemistry, (2) The Dynamac Corporation, Kennedy Space Center.

POS-5 Phenolic Content of Cattail (*Typha domingensis*) and Bulrush (*Scirpus californicus*) Extracts. M. T. GALLARDO, L. -B. MENDOZA GALVEZ, AND D. F. MARTIN. Institute for Environmental Studies, Department of Chemistry, University of South Florida, Tampa, FL 33620.

POS-6 Effect of Decomposition Time on the Phytotoxicity of Cattail (*Typha domingensis*). M. T. GALLARDO, M. J. COLLIER, M. D. PAPACHRISTOU, AND D. F. MARTIN. Institute for Environmental Studies, Department of Chemistry, University of South Florida, Tampa, FL 33620.

POS-7 Bioactive Products from *Typha domingensis*. M. T. GALLARDO(1), J. A. PIDALA(1), C.L. GEIGER(2), AND D. F. MARTIN(1). (1)Institute for Environmental Studies, Department of Chemistry, University of South Florida, Tampa, FL 33620, (2)Department of Chemistry, University of Central Florida, Orlando, FL 32816.

POS-8 Phytotoxicity of Cattail (*Typha domingensis*) Mulches. M. T. GALLARDO, P. ROSE, AND D. F. MARTIN. Institute for Environmental Studies, Department of Chemistry, University of South Florida, Tampa, FL 33620.

POS-9 Bioherbicidal Effects of Cattail (*Typha domingensis*) and Bulrush (*Scirpus californicus*) Extracts. M. T. GALLARDO, D. C. WILLIAMS, AND D. F. MARTIN. Institute for Environmental Studies, Department of Chemistry, University of South Florida, Tampa, FL 33620.

FLORIDA COMMITTEE ON RARE AND ENDANGERED PLANTS AND ANIMALS

FRIDAY, 8:45 AM PHYSICS 120
DEAN BAGLEY, UNIVERSITY OF CENTRAL FLORIDA, presiding

8:45 AM REB-1 The Demography and Relocation of *Warea amplexifolia* at Lake Griffin State Recreation Area. D. BLACK (1), A. M. BARD (2), AND I. J. STOUT, (1) Department of Biology, University of Central Florida, Orlando 32816-2368, (2) Florida Park Service, Apopka 32712. Work to restore degraded sandhill habitat of Clasping Warea (*Warea amplexifolia*) at Lake Griffin State Recreation Area was begun in 1994. Demographic studies of the population were intensified in 1996 and 1996-98 to document patterns of distribution, abundance, dispersal, and seed set. The populations are clumped as a result of the relatively short dispersal of seeds. Numbers of flowering plants have increased each year since most of the hardwoods were removed from the area occupied by Clasping Warea. Seeds from the restoration site have been planted in experimental plots within fire-maintained sandhill habitat elsewhere in the recreation area. Approximately 3% of the seeds germinated in the second spring after planting. El Nino droughts are associated with a high mortality rate in 1998. Success of the relocation remains unclear.

9:00 AM REB-2 Is Mitigation A Quick Fix?: The Effects of Standing Leaf Litter and Soil Salinity on Mangrove Mitigation. JENNIFER CSIK AND BARBARA ROTHSTEIN, PH.D. Biomedical and Environmental Advancement Magnet (BEAM), North Miami Beach Senior High School, 1247 NE 167th Street, North Miami Beach 33162. Mitigated and naturally propagated mangroves of varying ages were examined for standing leaf litter and soil salt content. Lowered soil salinity and increased leaf litter are delayed for extended periods and may prolong periods of slow growth.

9:15 AM REB-3 Response of the endangered scrub lupine (Lupinus aridorum J. M. McFarlin ex Beckner) to the atypical weather patterns of 1998. I. J. STOUT, S. J. WOIAK, AND D. BLACK. Department of Biology, University of Central Florida, Orlando 32816-2368. Unusually heavy winter rains followed by a spring-early summer drought during 1998 provided an opportunity to assess the reaction of the scrub lupine at three contrasting study sites. Individually marked plants on two soil types in western Orange County were observed monthly to document recruitment, survival, and reproduction; a third site on the Winter Haven

Ridge in Polk County was also monitored. Recruitment, survival, and reproduction were compared among sites for 1998. In addition, population performance at one site in 1998 was compared with long-term data collected at the site between 1991 and 1998. Population numbers on the three sites were severely reduced in November 1998 relative to November 1997. This work was supported by the U.S. Fish and Wildlife Service.

9:30 AM REB-4 Reproduction and Population Study Using 2- and 3-Dimensional Point Pattern Analyses of a Wading Bird Colony at Gatorland, Orange County, Florida. JODI DOSTER, WALTER K. TAYLOR, and JOHN WEISHAMPEL. Department of Biology, University of Central Florida, Orlando 32816-2368. A two year wading bird population study was initiated at the Gatorland Rookery located in south Orange County, Orlando, Florida. The purpose of the investigation is to determine reproductive success of the wading bird colony located in a 4.05-ha, alligator-breeding marsh in the eastern section of the park. Nine species of birds nested in the rookery. Four of these species are currently listed as species of special concern: Green Heron, Little Blue Heron, Snowy Egret, and Tricolored Heron. To determine reproductive success, nests were tagged; eggs laid and hatchlings produced were counted. Egg mortality and hatching success were monitored to determine survivability. Nestling and fledgling counts were used to document mortality of young. Point pattern analysis was performed to analyze distribution of nests. Nest density, nest site availability, and habitat could then be evaluated. Point pattern analysis allows one to discover trends and to understand patterns within the rookery to maintain its continued success. Nine-hundred eighty-eight nests were counted in the rookery from November 1997 to September 1998. This report details results obtained during the first season which terminated in October 1998. With the number of fledglings produced, the 1998 breeding season was successful.

9:45 AM REB-5 Historical records of mammals on a newly established National Wildlife Refuge in east central Florida. J. S. WEIDLICH AND L. M. EHRHART. Department of Biology, University of Central Florida, Orlando 32816-2368. Investigative research of the mammalian fauna of the barrier island complex in southern Brevard county during the late 19th century documented 17 species of terrestrial mammals and resulted in the establishment of seven type localities of mammalian subspecies. Of the 17 species documented, 2 are now listed. Historical accounts provide 4 additional mammals of which 3 are listed. Much emphasis in modern times has focused on a single species, the southeastern beach mouse (*Peromyscus polionotus niveiventris*), without addressing the current status of other mammals. Results from a mammal survey of over 11,000 trap nights indicates a decrease in the number of species compared to historical records and accounts, mainly due to development and urbanization of the barrier island. However, with the establishment of the Archie Carr National Wildlife Refuge in southern Brevard and northern Indian River counties, the remaining habitat can facilitate the survival of the remaining species and through restoration provide the necessary habitat for possible reintroduction.

10:00 AM BREAK

10:15 AM REB-6 Bat Conservation and Research in Florida. L.S. FINN. Fly By Night, Inc., 431 Sheryl Drive, Deltona 32738. In the last several years interest in bat conservation and research throughout the United States has increased significantly. Much of this increase is due to organizations such as Bat Conservation International. In Florida research and conservation efforts have been conducted by organizations including 3-D International, The Florida Bat Center, Florida Game and Fresh Water Fish Commission Biologists and Fly By Night, Inc. A summary of bat research and conservation efforts will be presented along with suggestions for future efforts.

10:30 AM REB-7 20 Years of Sea Turtle Conservation at the St. Lucie Nuclear Power Plant. JONATHAN C. GORHAM AND MICHAEL J. BRESETTE. Quantum Resources, St. Lucie Power Plant, 6451 South Ocean Dr., Jensen Beach 34957. Florida Power and Light's St. Lucie Nuclear Power Plant is located on South Hutchinson Island, St. Lucie County, Florida, an important nesting and developmental habitat for sea turtles, particularly loggerhead (*Caretta caretta*) and green turtles (*Chelonia mydas*). In this presentation we describe the sea turtle conservation program at the St. Lucie Power Plant and provide a brief overview of data collected to date. Over 6000 sea turtles have been captured, tagged and released from the intake canal at the power plant generating an extensive database and 20 years of sea turtle nesting surveys provide a valuable long term record of nesting on an important Florida sea turtle nesting beach.

10:45 AM REB-8 Marine Turtle Nesting At The Archie Carr NWR: Long-term Rising Trend Culminates in Record High Nest Production in 1998. L. M. EHRHART AND D. A. BAGLEY, Department of Biology, University of Central Florida, Orlando 32816-2368. Systematic, season-long surveys of marine turtle nesting have been carried out since 1982 in the part of south Brevard County now known as the Archie Carr NWR. Loggerhead nesting activity rose abruptly (52% above the previous long-term mean) in 1990 and has remained at that elevated level throughout this decade. Loggerhead nest production reached a new high level in 1998 (17,629), exceeding the previous high (seen in 1995) by 4%. Green turtle nesting at ACNWR has risen from fewer than 100 in the early 1980's to the previous high level of 1107 seen in 1994. The 1656 green turtle nests observed in 1998 exceeded the previous record by 50%. Prior to 1990, leatherback nesting at ACNWR was negligible. A small increase that began in the early 1990's culminated in the production of 20 leatherback nests in 1998. In summary, all three species of marine turtles that nest at ACNWR set new records for nest production in 1998.

11:00 AM REB-9 The Effect of Beach Nourishment on Marine Turtle Nesting and Reproductive Success at Sebastian Inlet, Florida. R. M. HERREN AND L. M. EHRHART. Department of Biology, University of Central Florida, Orlando 32816-2368. There are essentially two factors of beach nourishment that could affect the marine turtle nesting process. One is the impediment of gravid females affecting nesting success. The other is the disruption of the nest microclimate affecting reproductive success. The objective of this study was to compare nesting and reproductive success rates between two nourished beaches (treatments) and a natural (control) beach at Sebastian Inlet, Florida in 1996, 1997 and 1998. The results showed that a significant reduction in nesting success occurred in the nourishment year (1997), but nesting success rebounded a year later (1998). Reproductive success rates were significantly reduced in 1996 and 1997, but not in 1998. The physical properties of these beaches may have greatly influenced our results. In addition, the observed differences may have been the result of changes in beach profiles, inlet hydrology and rainfall totals during the three years.

11:15 AM REB-10 Prevalence and Severity Of Green Turtle Fibropapillomatosis in the Indian River Lagoon. S. HIRAMA AND L. M. EHRHART, Department of Biology, University of Central Florida, Orlando 32816-2368. Fibropapillomatosis (FP) is a debilitating disease which is found in all marine turtle species. It is, however, much more prevalent in the green turtle than in any other species. Since 1982, the UCF Marine Turtle Research Group has been capturing and examining juvenile green turtles, *Chelonia mydas*, in the Indian River Lagoon, just south of Sebastian Inlet, Indian River county. This study site is known for high prevalence of green turtle fibropapillomatosis. In 1996, we captured 272 green turtles; the prevalence of FP was 60.7%. In 1997, 32 of 66 green turtles exhibited FP. In 1998 the prevalence rose to 72.5%; 121 of 167 green turtles were afflicted.

11:30 AM REB-11 Characterization of a population of juvenile green turtles from an east central Florida developmental habitat. D. A. BAGLEY AND L. M. EHRHART. Department of Biology, University of Central Florida, Orlando 32816-2368. Sea turtle developmental habitats of the east central coast of Florida are utilized year round by juvenile green turtles *(Chelonia mydas)* and have been studied continuously by the U.C.F. Marine Turtle Research Group since the mid 1970s. Netting work began on the Sabellariid worm rock reefs in northern Indian River County in 1989. Since that time, 324 juvenile green turtles ranging in size from 25.1 to 70.8 cm. have been captured, examined, tagged and released. Based on a sample size of 100, the mean for this population is 40.1 cm. and approximately 68% are female. Results of mtDNA analysis reveal that, in terms of haplotypes, this is the most diverse habitat studied to date with nine of the known 18 haplotypes and three new haplotypes as yet still unidentified from nesting beaches. Maximum likelihood analysis suggests that 53% of these juveniles are derived from Florida and Mexico beaches and 42% are from Costa Rica. The remaining 6% come from other rookeries, and as far away as the Mediterranean.

11:45 AM REB-12 The effect of the 1998 El Niño on Wood Stork reproductive success in the Kissimmee River Basin. SUSAN E. RALLO AND I. JACK STOUT. Department of Biology, University of Central Florida, Orlando, Florida 32816-2368. Wood Storks (Mycteria americana) live up to 20 years and may breed 15 times over their lifespan. Successful reproduction is dependent on wet summers for the growth of prey populations and dry winters to concentrate the prey in wetlands. The El Niño of 1998 left Florida with an extremely wet winter and a short-term summer drought. Successful reproduction in the Wood Stork rookeries within the Kissimmee River Basin seemed to be in jeopardy as prey species were widely dispersed onto the flooded landscape. However, this proved to not be the case. With the end of winter rains and the onset of a short-term drought, nest building began in earnest in the three known colonies. High surface water in February delayed nest building until March. The total number of nests in all three colonies greatly exceeded those observed in 1997. Young Wood Storks were not to starve or be abandoned in 1998. Thus, the Wood Stork breeding in the three colonies in the Kissinnee River Basin was affected by the 1998 El Niño in timing, magnitude, and success of the reproductive season.

12:00 PM BUSINESS MEETING AND ELECTION OF NEW CHAIR ELECT
DEAN BAGLEY, presiding.

GEOLOGICAL AND HYDROLOGICAL SCIENCES

FRIDAY, 2:30 PM PHYSICS 130
DONALD LOVEJOY, PALM BEACH ATLANTIC COLLEGE, presiding

2:30 PM GHY-1 A Geochemical/Statistic Model on Heavy Metals in Aquatic Sediment Samples from Florida's Fresh Water Bodies, Paul Z. Lee, Ph.D., P.G., Florida Department of Environmental Protection, Twin Towers Office Building, MS 3565, 2600 Blair Stone Road, Tallahassee, 32399-2400. As an inseparable part of the natural water system, sediment plays an important role in material transportation, storage, transfer and interaction within a watershed, thus impacts the ecosystem and human health. Many previous methods to evaluate heavy metals contained in sediment use the bulk concentration of heavy metals. However, the bulk concentrations of heavy metals show no concordance with the biological impact data. To explore the potential of bioavailability of heavy metals in sediment, the model proposed several known geochemical mechanisms that may affect the bioavailability of heavy metals' bulk concentration.

2:45 PM GHY-2 Wakulla Springs Water Clarity Model, Paul Z. Lee, Ph.D., P.G., Florida Department of Environmental Protection, Twin Towers Office Building, MS 3565, 2600 Blair Stone Road, Tallahassee, 32399-2400. Edward Ball Wakulla Springs State Park features the spring that is the source of the Wakulla River. The spring vents into a clear pool, 180 feet in depth, that is exhibited to park visitors from glass bottom boats operated by park rangers. For decades, a darkening of the spring water, leading to reduced visibility and consequent docking of the boats ("down days"), has been observed following significant rainfall events. The dark water has at times been observed following minor rainfalls. A conceptual model of the hydrologic mechanisms causing the darkening of the spring water is presented. A simplified mathematical model, based on the conceptual model, is presented and calibrated with the available data concerning monthly rainfall and monthly "down days." The model can be used to predict glass bottom boat "down days."

3:00 PM GHY-3 An Evaluation of the Interrelationships of the Factors Describing Solute Transport in Ground Water. R.E. Copeland, Florida Department of Environmental Protection, 2600 Blair Stone Road, Tallahassee, FL 32301. Since the middle of this century, solute transport in ground water has been described by the linear, Advection-Dispersion equation. In one dimension, it is assumed that breakthrough curves (e.g. plots of output concentration versus time) should be adequately predicted by the equation if homogeneous conditions exist. Unfortunately, the equation does not always describe solute transport in a sufficient manner.

The problem was addressed using factorial design experiments conducted under near ideal conditions. The purpose was to evaluate the interrelationships of the various equation factors. According to Advection-Dispersion theory, the magnitude of dispersivity, a factor associated with the dispersion term, is a constant and is independent of the other factors. The laboratory experiments suggest that dispersivity is actually a function of the input concentration of the solute. This challenges the assumption that the system is linear and helps explain why the equation does not always describe the behavior of the system in a satisfactory manner.

3:15 PM GHY-4 A Guide to the Interpretation of Metal Concentrations in Freshwater Sediments. THOMAS P. BIERNACKI, Florida Department of Environmental Protection, 2600 Blair Stone Rd. MS 3525, Tallahassee, Florida 32399. Interpretation of environmental metals data is made difficult by the fact that absolute metals concentrations in freshwater sediments are influenced by a variety of factors, including sediment mineralogy, grain size, organic content, and anthropogenic enrichment. An interpretive tool provides a means of accounting for natural variability of metals and determining whether sediments are enriched with metals with respect to expected natural concentrations. The interpretive tool is based on the relatively constant natural relationships that exist between metals and aluminum. "Clean" freshwater sediments from throughout Florida were collected and their total metals content determined. Metal/aluminum regressions and prediction limits were calculated and diagrams of metal/aluminum relationships constructed. Metals data from freshwater sediments can be plotted on these diagrams to determine whether measured metal concentrations represent natural concentrations or metal enrichment.

3:30 PM GHY-5 State-wide Ambient Ground-water Quality Summary, 1994 - 1997: An Internet Application. J. V.-C. SILVANIMA, S. P. HANSARD, AND D. P. OUELLETTE, Florida Department of Environmental Protection, 2600 Blair Stone Rd., Tallahassee 32399-2400. The results of the most recent complete sampling of the background water quality of Florida's major potable aquifers are presented in an Internet Application. The Application consists of four interactive frames: a table of contents, two maps, and the text of the report. The report gives an overview of Ambient Monitoring of the state's potable ground-water resources, state-wide summary statistics per aquifer system for parameters sampled through the sampling period by each of 20 geographic regions, intended uses and limitations of the data, and Bibliography giving other sources of related information. The application is located on the Florida Department of Environmental Protection's Ambient Monitoring Section's home page at http://www.dep.state. fl.us/water/division/monitoring.

3:45 PM GHY-6 Puddle Formation in Large Drops at Low Reynolds Number in High Viscous Fluids: Flow Visualization and Preliminary Characterization of Motion. M. BOLAND (1), E. SHAFTLAND (1), P. ARCE (1, 2), and D. LOPER (2). (1) Engineering, FAMU-FSU College of Engineering, (2) Geophysical Fluid Dynamics Institute, GFDI, Florida State University, 2525 Pottsdamer Street, Tallahasse, FL 32310-USA. The motion of large drops in a high viscous fluid and at low Reynonds numbers is analyzed in this contribution. The experiments show very interesting puddle formation inside the drop caused by convective-diffusive mechanisms that seem to destroy the classical patterns given by the Hadamard-Rybcizki flow. The investigation will show experimental results and a preliminary characterization of some of the properties of the flow. Applications to the fluid dynamics of Earth mantle and viscous mixing will be addressed.

FRIDAY 4:00 PM
BUSINESS MEETING: GEOLOGICAL AND HYDROLOGICAL SCIENCES
DONALD LOVEJOY, presiding

MEDICAL SCIENCES

SATURDAY, 9:00 AM PHYSICS 130
ARVIND DHOPLE, FLORIDA INSTITUTE OF TECHNOLOGY, presiding

9:00 AM MED-1 Microhemodynamics in Arterial Stenosis Domains. T. CLOUD (1) AND P. ARCE (1). (1) Department of Chemical Engineering, University of Florida, Gainesville, FL 32611 (2) Chemical Engineering and Geophysical Fluid Dynamics Institute, GFDI, Florida State University, 2525 Pottsdamer Street, Tallahassee, FL 32310-USA. The role of convective-diffusive transport mechanisms in the growth of stenosis formation in human arteries is poorly understood. The physical situation is fairly complicated since pulsatile flow conditions and a variety of "blood particles" are present in the stenosis domain. In this contribution, three hemodynamic regimes are proposed to characterize the different regions that are most likely to develop a stenosis in the human body. These regimes lead to analytical solutions that are, then, effectively used to study the motion of blood particles towards the wall of the human artery.

9:15 AM MED-2 Effect of Various Dihydrofolate Reductase Inhibitors, Used Singly and in Combination, on In Vitro Growth of *E. Coli*. KARINE F. LEGRAND AND ARVIND M. DHOPLE Florida Inst. of

Tech. Dept. of Biology 150 West University Blvd., Melbourne, FL 32901. The action of diaminodiphenylsulfone, trimethoprim, pyrimethamine, brodimoprim and epiroprim, singly as well as in combination was determined on the in vitro growth of *E. coli*. Turbidity method was used to determine the MICs and the MBCs. Plating method was used to determine MBCs. Dapsone did not inhibit the growth of *E. coli* at any concentration. It was considered that trimethoprim at 100 μg/ml was bacterostatic. Pyrimethamine at 90 μg/ml and brodimoprim at 100 μg/ml were bacterostatic. Epiroprim at 80 μg/ml was bactericidal. The combinations of dapsone with trimethoprim, pyrimethamine, epiroprim or brodimoprim did not inhibit the growth of *E. coli*. The combinations of brodimoprim (70 μg/ml) with pyrimethamine (70 μg/ml), of trimethoprim (5 μg/ml) with pyrimethamine (100 μg/ml) were bacterostatic. The combination of epiroprim (50 μg/ml) with pyrimethamine (70 μg/ml) was bactericidal. The combinations of epiroprim (30 μg/ml) with brodimoprim (70 μg/ml), of epiroprim (40 μg/ml) with trimethoprim (5 μg/ml), and of brodimoprim (70 μg/ml) with trimethoprim (1 μg/ml) were bactericidal.

9:30 AM MED-3 Isolation of mRNA from Bahia Pollen and Preparation of a Complementary DNA Library. G. GHOBRIAL, N. RODRIQUEZ, R. GENNARO, S. KLOTZ, M. SWEENEY, AND R. WHITE, University of Central Florida , Department of Molecular Biology and Microbiology and the Center for Diagnosis and Drug Development, Orlando, 32816. Crude pollen extracts of BA, ME, and BO were partially purified by preparative scale isoelectric focusing (IEF), and the fraction obtained were analyzed using analytical SDS-PAGE. Three IgE-binding proteins from BA IEF fraction C (27, 32, and 34 kD) were purified. The IgE-binding glycoprotein with molecular weight of 32 kD and a pI of 6.92 is thought to be the major bahia allergen, because all tested BA allergic patient sera were reactive toward this component. Messenger RNA has been isolated from BA pollen and used to prepare a complementary DNA library. Allergic patient IgE is being used to screen clones for the recombinant allergen.

9:45 AM MED-4 Purification and Sequencing of the Major Allergen of Bahia grass. A. MAJIDI, N. RODRIQUEZ, R. GENNARO, S. KLOTZ, M. SWEENEY, AND R. WHITE, University of Central Florida, Department of Molecular Biology and Microbiology and the Center for Diagnosis and Drug Development, Orlando, 32816. The protein components of the crude pollen extracts of Bahia (BA) were purified using isoelectric focusing (IEF). Most of the protein components of BA separated in the pH range between 5 and 10. Three of these components of BA (27, 32, and 34 kD) were previously purified using continuous elution electrophoresis. The 32kD component of BA is a major allergen. Major allergens are those that more that 60% of allergic patients produce IgE toward. The 32 kD BA component is now being sequenced to determine amino acid composition and possible identification.

10:00 AM MED-5 In Vitro Evaluation Of Anti-Tuberculosis Drugs Against *Mycobacterium avium ss paratuberculosis* For Treatment Of Crohn's Disease. Dwight Campbell, Claudia Romero, Deidre Schwartz, Ira Shafran and Saleh Naser*. Molecular Biology and Microbiology, Center for Diagnostics and Drug Development, University Of Central Florida, Orlando, Florida. *Mycobacterium avium ss paratuberculosis (M para)* is the causative agent of Johne's Disease in ruminants and has been implicated in the pathogenesis of Crohn's disease (CD), a chronic inflammatory bowel disease in humans. Like members of *the M avium complex, M para* is resistant to anti-tuberculosis (anti-TB) drugs. In this study, seven anti-TB drugs (rifamipcin; RIF, streptomycin; SM, kanamycin; KM, clarithromycin; CLR, isoniazid; INH, pyrazinamide; PZA and ethambutol; EMB) have been tested *against M para* using the Bactec system. The MIC_{50} and $MIC_{99.9}$ for the drugs (where 50% and 99.9% respectively of the *M para* cells were inhibited or killed) were determined with KM, CLR and EMB produced significant inhibtion activity against *M. para.* To minimize drug resistance-induced strains, regimens of these drugs have been used for the treatment of mycobacterial infection. Our data show that a regimen consisting of RIF:EMB or RIF:CLR resulted in the significant *eradication of M para in vitro. In fact, the RIF:CLR combination produced similar results when used against two clinical strains of M* para that have been isolated from resected tissue of CD patients. RIF:CLR is recommended for in vivo eradication of *M para* because the spheroplast form of *M para* has been suggested as the virulent state of the bacterium in CD. These data also provide guidelines and possible protocols for the first-line drugs to be used in the treatment of CD.

10:15 AM MED-6 In Vivo Evaluation Of Anti-Tuberculosis Drugs For Treatment Of Crohn's Disease Patients. Ira Shafran, Dwight Campbell, Claudia Romero, Deidre Schwartz, and Saleh Naser*. Molecular Biology and Microbiology, Center for Diagnostics and Drug Development, University Of Central Florida, Orlando, Florida. A Crohn's patient who was found to be PCR positive for *Mycobacterium avium ss paratuberculosis (M. para*) with a positive serologic response to p35 and p36 antigens (recombinant clones expressing a 35K and 36K protein from *M. para* genomic library), has demonstrated significant healing (>80%) of an ulcer seen in the ileum at endoscopy. This healing was observed after the patient underwent a combination of Clarithromycin 250 mg. twice a day and rifabutin 150 mg. daily. He was endoscoped through his stoma and found to have a 4.0 cm. aphthous ulcer. The remaining ileum was unremarkable to a depth of 120 cm. Histology showed typical features of CD. He became asymptomatic in 2 weeks and a follow-up endoscopy was done after completing 1month of treatment. The 4 cm. ulcer, noted 1month before, had decreased to 1 cm with excellent re-epithelialization from the edge of the ulcer inward. The remaining ileum to 120 cm. was normal. The patient has remained symptom free and continues to be on antibiotics. This is the first known case of CD treated with this combination of antibiotics with documented clinical and endoscopic healing. The endoscopic observations reported further substantiate the possible role of *M para* in CD. Currently, 14 CD patients are undergoing similar treatment to further validate the role of *M para* in CD and the efficacy of antibiotic treatment.

10:30 AM MED-7 Zirconyl Hematoxylin Staining of Acidic Mucins. A. A. SMITH, Barry University, Miami Shores, FL 33161. Most stains for acidic mucins are time-consuming to prepare and have short working lives. Zirconyl hematoxylin is easily prepared and works for several months. It is made by adding 5 ml freshly-made 0.01% aqueous sodium iodate, 400 mg zirconyl chloride octahydrate, 45 ml 22% aqueous glycerol, and 5 ml glacial acetic acid, in that order, to 100 mg of hematoxylin in 5 ml of absolute ethanol. Zirconyl hematoxylin stains acidic mucins magenta. It stains the same mucins as Mowry's colloidal iron in mouse, sheep, and rhesus monkey salivary glands. It shows the same number of goblet cells in mouse rectum and duodenum as colloidal iron. Like colloidal iron, zirconyl hematoxylin stains the mucin of cancerous prostate tissue while leaving normal prostate unstained.

10:45 AM MED-8 How Diverse Are Our Medical Schools? S. SESODIA. School of Graduate Medical Sciences, Barry University, 11300 NE 2nd Avenue, Miami Shores 33161. Barry University is at the forefront of addressing the issue of student diversity at its campus. Currently, it is part of the Central and South Florida Higher Education Diversity Coalition. The School of Graduate Medical Sciences (SGMS) has been active in promoting the recruitment of culturally diverse students since its inception. However, the outcome of this activity has been based solely on the numbers of such students in the total student population. It is tacitly accepted that since the school has been successful in this process, and continues to be so, that the campus environment must be to the students' liking. This presentation will address whether the SGMS/University has met the students' expectations of the graduate environment on the basis of responses to a survey that was sent to all students in the SGMS. It examines the students' perceptions of what constitutes a culturally diverse environment and compares it to the faculty's perception of the same.

11:00 AM BUSINESS MEETING: MEDICAL SCIENCES
ARVIND DHOPLE, presiding

PHYSICS AND SPACE SCIENCES

SATURDAY, 10:00 AM PHYSICS 108
MARK MOLDWIN, FLORIDA INSTITUTE OF TECHNOLOGY, presiding

10:00 AM PSS-1 Exploring the Boundaries of Psi. C. CALTAGIRONE, J. LABARBERA, AND H. HICKMAN, Hillsborough Community College, P.O. Box 30030, Tampa, FL 33630. In 1953, Albert Einstein drew attention to the quantum mechanical analysis of a small ball rebounding elastically between two parallel walls placed normally on the x-axis at the points x = 0 and x = L. His purpose was to demonstrate that quantum mechanics is incapable of describing the real behavior of an individual system. Over the years Einstein's criticism has fallen by the wayside, but his example has evolved into the now-famous "particle in a box", found in almost every introductory quantum textbook. Confused by some author's treatment of the case x = - L/2 to x = + L/2, we generalized the limits, allowing the ball to rebound between x = A and x = A + L, where A could be any point on the x-axis. The form of the generalized wavefunction is somewhat interesting, and the associated momentum eigenfunction expansion also takes an interesting twist.

10:15 AM PSS-2 On the Outskirts of Faraday's Law. L. Hall, University of South Florida, 4202 Flowler Ave., Tampa, FL 33620. T. BEACHY, AND H. HICKMAN, Hillsborough Community College, P.O. Box 30030, Tampa, FL 33630. The magnetic field produced by a steady current flowing through an infinite solenoid is constant, and completely confined to the interior of the solenoid. Faraday's Law seems to predict that a change in the magnetic field inside the solenoid will produce a temporary electric field outside the solenoid. We used a quasi-static calculation to obtain a "first order" expression for the external electric field, and then built a long solenoid in order to test our prediction. Our analysis indicates that the electric field should fall off with distance as 1/r, and preliminary experiments agree.

10:30 AM PSS-3 Modern materials spectroscopy in an advanced undergraduate laboratory. B. Batsche II, D. L. Hannot, A. SCHULTE. Univ. of Central Florida, Orlando. Raman spectroscopy has undergone a technical revolution during the past decade with a surge of industrial applications. Due to the availability of moderately priced CCD systems and holographic filters a wide range of modern spectroscopic applications are within the scope of an advanced undergraduate laboratory. We describe experiments which illustrate the connection between basic physics and industrial applications and present fluorescence and Raman spectra of laser crystals, diamond thin films, and biological compounds. Supported by NSF, Grant No. DUE-9850934.

10:45 AM PSS-4 Introduction to Photoemission, LEED and AES. Shen Li Qiu and Hong Ma, Alloy Research Center, Department of Physics, Florida Atlantic University, Boca Raton, FL 33431-0991. Metallic alloys form a large class of scientifically interesting and technologically important materials. Properties, such as crystal structure, phase stability, electric behavior, magnetism and conductivity, are all related directly to the underline electronic structure, i.e., the distribution of electrons in space, momentum and energy. An ultimate goal of materials science is to understand at the fundamental level what gives rise such properties and to "design" alloys with superior properties for specific applications. It is essential therefore to develop the most sensitive probes of surface and bulk electronic structure in metallic alloys. Modern techniques such as photoemission, low energy electron diffraction (LEED) and Auger electron spectroscopy (AES) are used extensively in the investigations of the electronic structure and properties of metallic alloys. We introduce the basic mechanism for each of these techniques and present some photoemission spectra, LEED pattern and Auger spectra taken from metallic alloys.

11:00 AM PSS-5 Electronic Structure and Properties of Cu – Pd Alloys. Hong Ma and Shen Li Qiu. Alloy Research Center, Department of Physics, Florida Atlantic University, Boca Raton, FL 33431-0991. We have successfully made both poly-crystalline and single-crystalline Cu-Pd alloys with different compositions including $Cu_{85}Pd_{15}$, $Cu_{75}Pd_{25}$, $Cu_{59}Pd_{41}$ and $Cu_{50}Pd_{50}$. The crystal structures and lattice constants of all the samples have been determined using X-ray diffraction facilities. We have carried out surface studies on some of the Cu-Pd alloys using Auger electron spectroscopy (AES) and low energy electron diffraction (LEED) techniques. A series of photoemission measurements from both the poly-crystalline and single-crystalline CuPd alloy over the photon energy range from 30 – 115 eV have been performed at beamlines U7B and U4A at National Synchrotron Light Source (NSLS). We have done a series of theoretical calculations using the state-of-the-art computer codes including FLAPW, LMTO, RKKR, RXPS and RPHOT. Comparison between the experimental and theoretical results will provide new insights into many of the interesting and complex issues in alloy-physics directly in electronic terms.

11:15 AM PSS-6 Photoemission from the low index surfaces of equi-atomic Cu-Au alloys. R.G. JORDAN, Alloy Research Center and Department of Physics, Florida Atlantic University, Boca Raton 33431. I will discuss some recent measurements of the photoemission from the (001) and (100) surfaces of ordered, equi-atomic CuAu*I*, carried out as a function of photon energy. Deconvolution of the peaks in the spectra permits a determination of the binding energy shifts of the Cu and Au core levels at the surface compared with the bulk. I show that the results are sensitive to the orientation of the surface; furthermore, they are in good agreement with first-principles electronic structure calculations. The measurements were carried out at the National Synchrotron Light Source (NSLS) and the work is supported by the NSF (DMR-9500654).

11:30 AM PSS-7 HEMISPHERE: High School Experimental Magnetometer for Space Physics Education and Research. M. B. MOLDWIN AND H. K. RASSOUL, Dept. of Physics and Space Sciences, Florida Institute of Technology, 150 W. University Blvd., Melbourne FL, 32901. A low-noise, low-cost induction magnetometer is being built as a prototype for a new national high school magnetometer array called HEMISPHERE. The induction magnetometer will measure magnetic ULF waves and will be built, tested, and operated by selected High School teachers and their teachers. The projected is being supported by NOAA and NSF.

11:45 AM PSS-8 Chemical Bath Deposited CdS on CIS Solar Cells. W. JUNEK, J. UNDERWOOD, AND R.P. RAFFAELLE, Dept. of Physics and Space Sciences, Florida Institute of Technology, 150 University Blvd., Melbourne 32901. We have been investigating the chemical bath deposition of cadmium sulphide (CdS) on electrochemically deposited copper indium diselenide (CIS) thin films. CIS is commonly used as an absorber material in thin film photovoltaic solar cells due to its extremely high optical absorption coefficient and suitable bandgap and electrical characteristics. We have potentiostatically electrodeposited p-type thin films of CIS. These films were subsequently annealed in argon and characterized by energy dispersive spectroscopy and x-ray diffractometry. Chemical bath deposition (CBD) was used to grow thin films of CdS on our CIS films. CdS provides a well lattice-matched wide bandgap window material which can be used with CIS to make photovoltaic *pn* junctions. We have measured the electrical characteristics of our junctions as a function of the (CBD) conditions. We will discuss the effects of temperature and pH on the photovoltaic performance of our cells.

SATURDAY 12:00 AM
BUSINESS MEETING: PHYSICS AND SPACE SCIENCES
MARK MOLDWIN, presiding

SCIENCE TEACHING

FRIDAY, 10:00 AM PHYSICS 130
DAVE SHELDON, VALENCIA COMMUNITY COLLEGE, presiding

10:00 AM TCH-1 Identification of Aquatic Algae by Narrow Band Spectrophotometry and HPLC; A Comparison J.D. PATTERSON, Valencia Community College, Orlando Fl. And Rollins College, Winter Park, Fl. Samples from the lake Dora canal and lake Eustis where collected and processed rapidly in the field for later analysis in the laboratory. Two methods where compared for qualitative and quantitative analysis of pigments used as indicators: HPLC and narrow band pass spectrophotometry. Further development of the HPLC technique has incorporated an isocratic solvent system for species specific pigment profile analysis. Verification by microscopy was also carried out. Samples where taken over a ninety day period. Although inconclusive as to seasonal algae distribution, these studies indicate that spectrophotometry for qualitative analysis is more rapid and applicable to field studies. In contrast, HPLC, while quantitative is not easily performed in the field but can corroborate the data obtained by spectrophotometry and microscopy.

10:15 AM TCH-2 Enhancing Minority Interest in the Biological Sciences Through Research Internships T.P. ARNOLD, F.A. FRIERSON, J.D. PATTERSON and R.J. KEIPER, Valencia Community College, Science Dept., West Campus, P.O. Box 3028, Orlando, Fl. 32802. Valencia Community College in partnership with the University of Florida and the University of South Florida has instituted a student internship program targeted at under-represented minorities to encourage interest in further biological and biomedical studies. Students are recruited at Valencia community college and trained in basic research techniques. The following summer these students are paired with mentor /researchers at a university for a paid summer internship. In its first year this program successfully placed seventeen interns, eleven at USF and six at UF. In its second year, this program has enroled twenty seven students. This program is supported by a grant from the National Institutes of Health.

10:30 AM TCH-3 The Arboretum of the University of Central Florida: Fifteen Years of Educational Programs. H. O. WHITTIER (1) AND B. A. WHITTIER (2). (1) Dept. Biology, Univ. Central Florida, Orlando 32816-0368. (2) Lyman H.S., Longwood. Established on the east-central UCF campus in 1983 on 12 acres of pond pine wetlands, the Arboretum now has almost 68 acres of additional native habitat including cypress dome, *Nyssa* pond, longleaf pine flatwoods, oak scrub and sandpine-wild rosemary. Nearly three miles of trail connect the habitats. The facility serves as an interdisciplinary outdoor living laboratory for more than a thousand students a semester, and annually nearly 10,000 visitors from the University's Central Florida service area and beyond. An additional 500 acres, set aside as Nature Preserve, are under separate management for restricted research. A refurbished 24 X 60 foot portable building serves as Environmental Center, equipped with teaching library, computers with ethernet, hospitality area, intern offices and a small classroom. Programs utilizing the new Environmental Center, Arboretum facilities and plans for the future are discussed.

10:45 AM TCH-4 How Do Science Magnet Students View Themselves? BARBARA E. ROTHSTEIN, PH.D., MARK GOTTFRIED, PH.D., RAYMOND L. FONTANA, ALLYN BERNSTEIN, PH.D., BARBARA LICKSTEIN AND PHYLLIS BAKER, Biomedical and Environmental Advancement Magnet (BEAM), North Miami Beach Senior High School, 1247 NE 167th Street, North Miami Beach, Florida 33162. Students applying for and entering the BEAM program were questioned as to how they viewed themselves. They were again questioned about this during their first year. This preliminary study examined the original and changing view as related to sex and ethnicity.

11:00 AM TCH-5 Biochemistry Laboratory: Introduction of a Lab Practical Exam to Improve Student Preparation. D. W. LOUDA, Department of Chemistry and Biochemistry, Florida Atlantic University, Boca Raton 33431. Biochemistry Laboratory is a junior level course which introduces students to a variety of fundamental biochemical methods. Over the past decade, this class has expanded to become a required or recommended course in a number of different degree programs in chemistry, biochemistry, biology, medical technology, and biotechnology. As a result, students enter Biochemistry Laboratory with vastly different levels of laboratory experience. To insure that all students, regardless of their initial laboratory expertise, will be able to understand and perform the relatively sophisticated techniques used in Biochemistry Laboratory, a lab practical exam has been introduced. At the beginning of the course, students must satisfactorily complete a short, simple experiment dealing with the identification and quantification of biomolecules, using such basic methods as spectroscopy and pH measurements. Students with weak laboratory backgrounds are allowed extra time during the first week of the class to practice and improve their skills before moving on to the more difficult experiments of the course. The design of the lab practical exam is discussed, as is the effect of the lab practical on overall student performance.

11:15 AM TCH-6 Biochemistry Laboratory with a Comparative Methods Focus. D.W. LOUDA, Department of Chemistry and Biochemistry, Florida Atlantic University, Boca Raton 33431. Biochemistry Laboratory is an upper division course which exposes students to important biochemical techniques and also prepares students for advanced study in biochemistry. One aspect of designing the Biochemistry Laboratory course is the large number of methods, both traditional and modern, which students must master in order to be well-versed in biochemical analysis. To increase the number of techniques presented in Biochemistry Laboratory, an emphasis on comparative methods has been introduced. Each experiment is performed using two or three different techniques, and the various methods are then compared with regard to resolution, sensitivity, speed, sample capacity, ease of obtaining results, ability to recover biomolecules, etc. This approach not only gives students experience with numerous biochemical techniques, but also facilitates student comprehension as the similarities, differences, advantages, and limitations of the various methods are explored. Specific experiments and the impact of the comparative methods focus on student performance are discussed.

11:30 AM TCH-7 Active Learning in a Physical Science Course. R.G. JORDAN, Department of Physics, Florida Atlantic University, Boca Raton, FL 33431. In this short presentation I will outline the main ideas underlying active learning and describe some of the many benefits to students. The introduction of non-traditional teaching methods in the classroom, like active learning, are often viewed with skepticism by instructors and students alike, but I will describe specific examples that I use in a physical science course for non-science majors. I will show that a number of these ideas can be introduced in a straightforward way and without a great deal of effort on the part of the instructor.

11:45 AM BUSINESS MEETING: SCIENCE TEACHING
DAVE SHELDON, presiding

SOCIAL SCIENCE

FRIDAY, 2:30 PM PHYSICS 109
CHRISTOPHER CRONIN, SAINT LEO COLLEGE, presiding

2:30 PM SOC-1 A Formula for Success: Predictive Models of Retention and Arrest for Florida Drug Court Participants. A. L. HAAS, R. H. PETERS, AND M. R. MURRIN, Louis de la Parte Florida Mental Health Institute, Dept. of Mental Health, Law, and Policy, 13301 Bruce B. Downs Blvd., Tampa, FL 33612. Drug Court programs have been in used in Florida as a diversion program for drug-related offenders for several years. The current study examined factors influencing retention and follow-up arrest in the Escambia County drug court program. The purpose of this study was to examine characteristics of drug court graduates and non-graduates, and to determine whether characteristics of drug court participants predicted retention in the drug court program or arrest during a 30-month follow-up period. Using Cox regression analyses, results from the study indicated that the most important predictors of program graduation were: (1) type of substance identified as primary problem, (2) type of legal charges against participant, (3) current living arrangements, and (4) current employment status. The most important predictors of re-arrest during follow-up were the participant's age and primary substance abuse problem. Implications for drug court screening, admission, and treatment will be discussed in addition to directions for future research.

2:45 PM SOC-2 The Effect of a Video Presentation on Capital Punishment Opinions, JENNIFER WATSON, Saint Leo College, Saint Leo 33574. This study is an attitude measurement of the opinions that college freshmen have on capital punishment. There are three groups, one control and two experimental. The control group will complete the *Capital Punishment Survey*. These results will be used as a base line by which to judge the affect of the video on the experimental groups. Experimental Group number one will watch a ten-minute video that portrays a positive view on capital punishment followed by the same survey. Experimental group number two will watch a ten-minute video that portrays a negative view on capital punishment followed by the same survey. The author predicts that the opinions of Experimental Group number one will follow that of the video. The author further predicts that the opinions toward capital punishment of Experimental Group number two will not be affected by the video presentation.

3:00 PM SOC-3 Social Anxiety, Self-consciousness, and the Recall of Interpersonal Information. L. B. GOODMON (1) AND R. MEDLIN (2), Stetson University, DeLand 32720. Individuals with social anxiety are thought to lack social skills because they tend to talk less during social interactions. However, research suggests they cannot remember information exchanged during an interaction and therefore, cannot give proper feedback. These memory deficits are thought to be caused by anxious self-preoccupation, which disrupts encoding of events. Twenty-five people with high social anxiety and twenty-two people with low social anxiety, as measured by the Social Avoidance and Distress Scale, participated in a structured high or low evaluative interaction with a confederate of the opposite sex. Following the interaction, participants were asked to recall information about the interaction partner's background, interests, and appearance. Participants were given the Modified Self-consciousness scale, which measured public self-consciousness, private self-consciousness, and state anxiety during the interaction. Results failed to support the hypothesis that people with high social anxiety would recall less interpersonal information than people with low social anxiety. People with high social anxiety reported more public than private self-consciousness in both the high and low evaluative conditions.

3:15 PM SOC-4 Stimulus Change Disrupts Memory at Immediate but Not Delayed Tests in Neonatal Rats. R.G. BRYAN, Saint Leo College, Saint Leo, 33574. This experiment tested a hypothesis recently advanced by Riccio, Rabinowitz and Axelrod (1994) that forgetting of stimulus characteristics over time will prevent memory disruption at delayed tests that would otherwise occur at immediate tests. One week old rats were classically conditioned using a CS+ odor paired with the presence of a sibling US in the context of a CS- odor paired with the absence of the US. As predicted by the hypothesis, increasing changes in CS- context during testing produced increasing memory disruption at an immediate test but not at a delayed test 24 hours later.

3:30 PM SOC-5 Reform and Enlargement of the U.N. Security Council. MARCO RIMANELLI, Center on Inter-American Studies-Saint Leo College, St.Leo 33574. Since 1945, the U.N. Security Council promoted international security among its members, but often failed during the Cold War. A less visible controversy focuses on its actual representation and composition: 5 members (USA, USSR, Britain, France, China) are permanent, veto Powers, while other 5 are non-permanent ones on a biannual rotation base. In 1963 the U.N. General Assembly grew from 50 to 100 members, and the Security Council to 15 members (5 permanent, 10 non-permanent). By 1993, Decolonization and the break-up of the USSR and Yugoslavia expanded U.N. members to 180 States with new calls to members backfired, leading to generalized pressures for a democratic, geographical and representational enlargement for Third World members. But since 1993 the U.N. "Never-ending" Reform Committee is stalled on competing proposals: total seats (17-18), permanent vs. non-permanent ones, veto vs. non-veto, geographic representation between rival regional blocs (West, East Europe, Latin America, Asia, Africa, Arab States), rotation (Italian and African proposals), transparency. This essay studies the various political agendas, and leading U.S. and Italian position.

3:45 PM SOC–6 Integrating the use of Computers into a Great Books / Good Discussion class format. Dr. Hudson Reynolds and Aurora Vaca. Honors Program, Saint Leo University, St. Leo 33574. In the fall of 1998, the freshmen honors students at Saint Leo College were given computers for academic use. The beginning honors course, Classical World View, was taught using computers to enrich and supplement the content, namely, Greek literature in translation. A wide variety of techniques were employed, including online syllabi, notes, archives, and links; email assignments; individual portfolios; threaded discussions; multimedia presentations; chat room meetings; and site building. Moreover, the honors core course was linked to two English composition courses, so that assignments, projects, and themes could be reinforced and integrated across the curriculum. Midterm student evaluations were conducted, and external evaluation teams were brought in to interview the students in two-hour sessions. The formal report and midterm evaluations will be shared, and the class site will be reviewed, along with several student portfolios. The instructor and one of the students from the class will conduct the presentation, so that both sides of this process will be open to examination.

4:00 PM SOC-7 Marijuana use and marijuana-related problems among college students. C. CRONIN, Saint Leo College, St. Leo 33574. Three hundred forty-two students at a liberal arts college in Florida (178 males & 164 females, mean age = 20) reported on marijuana use, incidence, and desirability of marijuana-related problems and perceived risk of marijuana use. Results indicate a lifetime prevalence of 49.4% annual prevalence of 45% and a 30-day prevalence of 25% for marijuana use. These rates are slightly higher than rates reported for 171 colleges using the CORE Alcohol and Drug Survey, which found 31.3% and 18.6% for one year and 30-day prevalence, respectively. A similar study at a university in the southeast found comparable rates of 38% and 23% for one year and 30-day prevalence, respectively (Syre, et al., 1997). Students also completed a preliminary measure of marijuana-related problems. Reports suggest a significant percentage of students experiencing marijuana-related problems such as unclear thinking, increased forgetfulness, decreased energy level, decreased motivation, decreased academic performance, legal difficulties, relationship problems, etc. These data indicate that marijuana-related problems are more prevalent then the literature suggests and supports the goal of developing a Marijuana-Related Problems Scale.

FRIDAY 4:15 PM
BUSINESS MEETING: SOCIAL SCIENCE
CHRISTOPHER CRONIN, presiding

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